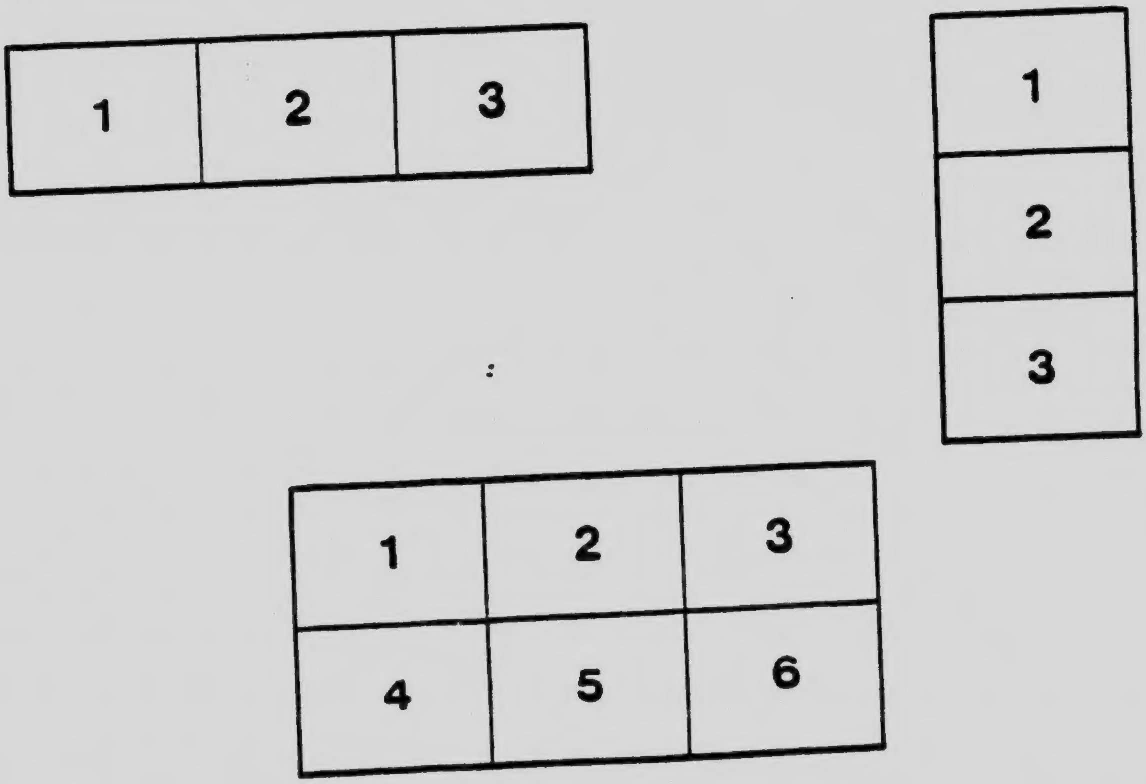
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CANADA

DEPARTMENT OF MINES

HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

BULLETIN No. 12

Investigation of a Reported Discovery of Phosphate in Alberta

BY

Hugh S. de Schmid, M.E.

OTTAWA
GOVERNMENT PRINTING BUREAU
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LETTER OF TRANSMITTAL.

Dr. Eugene Haanel,
Director Mines Branch,
Department of Mines,
Ottawa.

Sir,—

I beg to submit, herewith, the results of my investigation of the reported discovery of phosphate rock in the vicinity of Banff, Alberta.

I have the honour to be,
Sir,
Your obedient servant,

(*Signed*) **Hugh S. deSchmid.**

Ottawa, January 14, 1916.

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INVESTIGATION OF A REPORTED DISCOVERY OF PHOSPHATE IN ALBERTA.

INTRODUCTORY.

On September 10, 1915, the announcement was made public by the Commission of Conservation, that officers of the Commission had discovered rock phosphate within the limits of the Rocky Mountain Park, near Banff, Alberta.

The great potential value of deposits of phosphate at such a point, for eventual use in the manufacture of superphosphate for western lands, lent considerable interest to the discovery; since up to this time no sedimentary phosphates of any economic importance had been reported within the Dominion. The only occurrences of such sedimentary material hitherto known were certain low-grade coprolitic beds, containing *Lingulae*, in the Potsdam series of the Provinces of Quebec and Nova Scotia; and a thin "bone-bed" layer in Niobrara beds of the Cretaceous formation on Wilson river in Manitoba. Neither of the foregoing possesses any economic value whatever, the percentage of $Ca_3(PO_4)_2$ in the first-named being only from 36 to 44, and in the second 37·70.

Accordingly, the author was instructed to proceed to Banff, with a view to estimating the economic importance of the reported phosphate discovery. Banff was reached on October 1, and the field work, which yielded the results set forth in the following pages, occupied from 1st to 22nd of the month. A definite phosphate horizon in the Rocky Mountain Quartzite series was determined, and the bed was measured and sampled at a number of different localities.

The writer desires to express his acknowledgement to Mr. W. J. Dick, of the Commission of Conservation, for kindly placing at his disposal samples of the phosphate found in the Rocky Mountain Park, together with details relating to its discovery.

To Mr. S. J. Clarke, Superintendent of the Rocky Mountain Park, Banff, the writer's thanks are due for kindly affording him the use of an office.

To Mr. J. T. Child, Parks Engineer, also, thanks are extended for many courtesies.

NATURE OF THE PHOSPHATE DISCOVERY BY OFFICERS OF THE CONSERVATION COMMISSION.[1]

The occurrence of rock phosphate of economic value near Butte, Montana,[2] at points some 200 miles south of the International boundary, was investigated and reported on by the United States Geological Survey between 1911 and 1914; the latest report being that of Stone and Bonnie, on the Elliston area referred to in the accompanying footnote. The possibility of the Montana beds extending north into Canada had frequently been suggested, but the northerly continuation of the series appeared to be interrupted south of the border by what is known as the Lewis overthrust, a major fault which has resulted in the over-riding of the phosphate-bearing Carboniferous (Pennsylvanian) series by a considerable thickness of later beds.

However, in order to ascertain whether a phosphate-bearing horizon did not possibly exist in beds of Pennsylvanian (Upper Carboniferous) age in Canada, the Commission of Conservation deputed Dr. F. D. Adams and Mr. W. J. Dick to proceed to Alberta and Montana, and if possible to correlate Pennsylvanian horizons of the Eastern Rocky Mountains with what has been termed the Phosphoria formation, in Montana.

These officers succeeded in finding phosphate at two points in the Rocky Mountain Park, within a few miles of Banff.

The more important of these finds was that of a piece of float phosphate (a boulder weighing about 30 pounds) in the bed of Forty-mile creek, about 2 miles northeast of Banff (see map).

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[1] Particulars of the discovery have since appeared in a special Bulletin issued by the above Commission, entitled, "Discovery of Phosphate of Lime in the Rocky Mountains," by Dr. F. D. Adams and J. W. Dick.

[2] See Pardee, J. T., Bull. No. 530-H., U. S. Geol. Surv., 1912, pp. 20-27; Gale, H. S., Bull. No. 470, U. S. Geol. Surv., 1911, pp. 440-451; Stone, R. W., and Bonnie, C. A., Bull. No. 580-N., U. S. Geol. Surv., 1914.

This boulder consisted of phosphate of a dark, almost black colour, fine grained, and bearing close resemblance to a basaltic rock. The phosphoric acid content was 25 per cent. The bed from which the boulder originally came was not found, but the size of the mass led to the inference that a phosphate bed of some thickness probably existed somewhere in the more or less immediate vicinity.

The other discovery was of a small amount of phosphate, somewhat similar in character to the above, in the form of small impregnated zones in a quartzite ledge on Stoney Squaw mountain, the ledge being near the contact of the Rocky Mountain Quartzite with the underlying Upper Banff Limestone: both of Pennsylvanian age.

In addition to examining the Banff area, the aforementioned officers visited the Flathead region, in Southern Alberta; but made no discovery of phosphate in this latter section.

AREA EXAMINED.

All the field work in connexion with the writer's examination of the Banff district was conducted from Banff, no extended trips to the north or south being made.

The area examined is shown in the accompanying map, No. 387.

The geology of the Banff area is best explained by reference to this map. As will be noted, the occurrence of several more or less north and south faults has resulted in the formation of a series of fault-blocks, which are tilted rather steeply to the west and partially over-ride each other in an easterly direction. In this manner, we find a succession of north and south mountain ranges in which the same geologic horizons are repeated with more or less similarity from west to east. In the case of the Cascade Mountain fault, the vertical throw is believed to be in the neighbourhood of 3 miles.

The following extracts from J. A. Allan's account of the geology of the Banff district are taken from Guide Book No. 8, XII International Geological Congress, Excursion C 1, Part II, pp. 186-190:[1]—

[1] Copies of this Guide Book may be obtained by application to the Director, Geological Survey, Department of Mines, Ottawa.

Bankhead, Alt. 4,510 ft. About one mile east of the Bankhead siding, the railway leaves the bottom of Cascade valley and, turning at 90 degrees to the southwest, passes between Cascade mountain on the north, and Tunnel mountain on the south. This was at one time the course of Bow river, but the channel was obstructed by the gravels brought down by Forty-mile creek, as well as by the moraine left by the continental ice-sheet, so that now the Bow passes through this range between Tunnel mountain and Mt. Rundle.

The structure of the beds in Cascade mountain is well shown in the cliff to the right of the railway. The beds are steeply dipping to the west and terminate in a precipitous cliff on the east. The cliffs at the base are Intermediate Limestone (Devonian), overlain by Lower Banff Limestone (Lower Carboniferous). The Lower Banff Shale above (also Lower Carboniferous) weathers into talus-covered slopes. The mountain is capped by Upper Banff Limestone and Rocky Mountain Quartzite (Upper Carboniferous). An overthrust fault-line scarp defines the steep eastern face of this mountain; the Devonian limestones are thrust over the Cretaceous coal measures. This fault-line defines the southwest side of Cascade valley. It is exposed in the base of the Three Sisters, and extends to the southeast along the eastern face of the Livingstone range at the Crowsnest Pass, and into Montana, where it is known as the "Lewis thrust." It has not been possible to measure the actual amount of displacement, but there is a vertical throw of about three miles in Cascade mountain. McConnell has estimated that the front ranges of the Rocky mountains have been thrust about seven miles over the plains to the east, but it is not possible to measure the horizontal displacement in the Cascade Mountain thrust-fault.

A spur runs from Bankhead station to the Bankhead coal mines, about two miles to the northeast. These mines are owned and operated by the Canadian Pacific Railway Company. They are situated in the Kootenay coal measures, which are Lower Cretaceous in age. The coal is bituminous and semi-anthracite. The plant is well equipped with a large breaker and a briquetting mill.

Between the coal mines and Lake Minnewanka, a section along Cascade river exposes Cretaceous, Jurassic, Permian and Upper Carboniferous beds. Fossils are abundant, especially in the Rocky Mountain Quartzite. For a portion of this distance the driveway follows along the top of a morainal ridge. In pre-Pleistocene time, Cascade river drained out by Lake Minnewanka and Devil's Gap to the plains, but in recent time it has cut through the thick morainal detritus and has joined Bow river four miles east of Bankhead station.

Banff, Alt. 4,521 ft. This is the gateway to the Rocky Mountain National Park. This reservation covers 5,732 square miles. The town lies west of Tunnel mountain. On the north side of the valley are Cascade mountain and a subsidiary ridge, Stoney Squaw mountain, in which is shown the eroded end of an asymmetrical, anticlinal fold.

A few yards to the west of the station Bow river turns sharply to the southeast, and after passing the town and cascading over a very picturesque

fall, it is joined by the Spray. At this point, close to the Banff Springs hotel the river is diverted at right angles to the east and passes between Tunnel and Rundle mountains. The valley of the Spray river is floored with soft Permian and Jurassic shales. This valley is defined by a fault so that the beds in Sulphur mountain repeat those exposed in Cascade and Rundle mountains. The Fernie shales (Jurassic) are characterized in certain layers by an abundance of ammonites.

On the east slope of Sulphur mountain are situated the hot sulphur springs. The upper one is 500 feet above the town. The water comes from the orifice at a temperature of 114·2 degrees Fahr. This sulphuretted water has a marked medicinal effect, and many people visit Banff on this account. A second or middle hot spring is 200 feet lower down the slope, and a mile and a half farther to the northwest. This spring is not so strong as the upper one, and the temperature of the water is about 90° F. A third or lower spring is situated farther to the northwest and about 50 feet above Bow river. The water is at a lower temperature than either of the upper two. Locally this spring is spoken of as the "Cave and Basin," because the spring rises into a cavern about 20 feet in diameter. By means of an underground channel it escapes to a natural basin formed in calcareous tufa deposited. A second cave has been recently discovered a few yards farther up the slope. The interiors of these caves are coated with sulphur crystals. Other warm springs are located in the bottom of Bow valley, about the Vermilion lakes. All of these springs are located in the Intermediate Limestone (Devonian).

From the summit of Sulphur mountain can be seen the general monoclinal structure of this portion of the Rocky mountains. The successive ranges from the Cascade valley westwards represent westerly-dipping fault-blocks, which have become tilted along the east side. On the north side of Bow valley, the Cascade, Vermilion and Sawback ranges form distinct units, the same beds being repeated in each of these ranges.

Leaving Banff station, the railway follows along the broad, swampy valley of the Bow, on the right of which is a series of three small lakes, called Vermilion lakes. The range to the right is the Vermilion range, in which are exposed the westerly-dipping Devonian, Carboniferous, Permian and Jurassic beds.

Forty-mile creek follows a fault line which divides the Vermilion Lake range from the Sawback range. The depression to the right leads to Mt. Edith pass, beyond which can be seen Mt. Edith, which is made up of vertically-dipping Lower Banff Limestone. The steeply-dipping beds on the west of this creek belong to the Sawback formation. This formation lies conformably under the Devonian Intermediate Limestone, but the exact age is still doubtful, as no fossils have yet been found in it. Lithologically, a part of this series resembles the rocks of Silurian age in the Beaverfoot range to the west. To the south of the railway is the valley of Healy creek which extends to Simpson pass, and is the course followed en route to Mt. Assiniboine, the

Matterhorn of the Canadian Rocky mountains. Bow river has here a meandering course, some of the lobes having been cut through, to form oxbow lakes.[1]

As explained above, and as will be clear from the map, there are in this district a series of steeply-tilted, northwest and southeast fault-strips, averaging from 2 to 5 miles in width, in each of which is repeated a succession of rocks ranging in age from Devonian to Permian, and consisting of limestones, shales, quartzite, and chert, the youngest beds lying to the west. Each of such strips constitutes a mountain range, whose beds dip more or less steeply to the west. A system of four such fault-blocks is shown on the map.

The Rocky Mountain Quartzite beds in each of these four belts may, for the purpose of this report, be conveniently referred to as under, proceeding from west to east:—

I. Sawback Range belt.
II. Sundance Canyon—Mount Norquay belt.
III. Mount Rundle—Tunnel Mountain—Stoney Squaw Mountain—Cascade Mountain belt.
IV. Carrot or Stony Creek—Devil's Canyon belt.

At each of the spots named the Rocky Mountain Quartzite was examined for phosphatic horizons.

GEOLOGIC HORIZON OF THE PHOSPHATE BED.

In the Banff area, the phosphate horizon lies in the upper portion of the Rocky Mountain Quartzite (Pennsylvanian), at a probable average distance of from 25 to 75 feet below the Permo-Pennsylvanian contact. The actual contact of the Permian shales with the Rocky Mountain Quartzite was observed at only one of the points where the phosphate horizon was exposed, erosion having removed the soft shaly layers in each instance, leaving only a dirt cover resting against the tilted chert beds. At the bend of the Bow river, however, on the west side of Tunnel mountain, opposite the Banff Springs Hotel, the Permian shales appear to occupy almost the whole if not the whole

[1] Substantially the same information as above is contained also in "Guide to the Geology of the Canadian National Parks," by C. Camsell, pp. 48-50, and published by the Dominion Parks Branch, Department of the Interior, Ottawa.

of the river bed, the left or east bank here being formed of a steep cliff of chert some 40 feet in height. (See Plate IX). The phosphate bed at this point lies under 10 feet of chert. There was too much water in the river, however, to ascertain whether the shales in the river bed extend right up to this chert cover or whether the actual contact is some feet out from the shore.

By the phosphate horizon above referred to, is meant the main phosphate bed; many of the cherty layers of the Rocky Mountain Quartzite, and also of the thin shaly partings between individual quartzite and chert beds, are phosphatic to a minor degree, and are, therefore, to be included in the Phosphoria formation.[1]

It should be here stated that it has not yet been satisfactorily determined whether the age of the Phosphoria beds in the western United States is Pennsylvanian or Permian. If it should be ultimately shown that the latter is the case, the Rocky Mountain Quartzite in the Canadian Rockies may probably have to be assigned to this formation also, since there is no reason to doubt that the Phosphoria beds are contemporaneous throughout the entire area.

The dark chert underlying the Phosphoria formation proper is, perhaps, the most conspicuous and useful geologic indicator in the Banff district for tracing the phosphate bed. This chert is, on fresh surfaces, quite black in colour, is dense and compact, and has a chippy, angular fracture. Where exposed to the action of water, it commonly becomes friable, and can be rubbed in the hand to small angular fragments. This latter material strongly resembles coal.

The dark chert series probably averages about 50-75 feet in thickness, and in its lower portion forms 3 to 12 inch beds, separated by dark-brown, earthy-weathering shales. These lower chert layers are, commonly, somewhat lighter in colour than the upper beds, owing to the presence in them of minute white specks (probably organic remains), and they have a more matt or earthy appearance.

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[1] The term "Phosphoria formation" has been given to the phosphate-bearing beds of similar age in Idaho, Utah, and Montana: see Bull. No. 577, U. S. Geol. Surv., pp. 22-29.

The chert overlying the phosphate is lighter in colour than the above-described lower beds, is less dense and weathers to a rusty and somewhat cavernous rock. It may be described, perhaps, as an intimate mixture of light coloured quartzite and dark chert, rather than as a true chert as understood above. Its colour, however, is sufficiently dark to distinguish it from the true quartzites which succeed the chert series; and it thus serves as a useful indicator of the phosphate bed below it in cases where the lower chert layers are concealed. As already stated, this upper chert often contains pink, purple, or whitish fluorite, and though not actually tested, is very probably phosphatic to a minor degree.

The succession of beds in the Upper Rocky Mountain Quartzite, as exposed in one of the most ideal sections encountered in the area, was measured in detail in Sundance canyon and is shown below.

Beneath the upper, phosphate-bearing beds and the succeeding dark cherts follows a series of light coloured, calcareous quartzites, sometimes separated by shaly partings, and these beds become gradually more calcareous or dolomitic until they merge finally into the upper portion of the Lower Pennsylvanian or Upper Banff Limestone, which in its upper beds consists of dark coloured, crinoidal and fœtid magnesian limestones.

The total thickness of the Rocky Mountain Quartzite in the Banff district, as given by Daly,[1] varies in the different fault blocks from 800 to 1,600 feet.

A common fossil in the quartzite is the typical carboniferous coral Zaphrentis, which is often seen standing out on the weathered surface of the quartzite ledges.

The bed directly underlying the phosphate horizon is commonly a massive quartzite containing an appreciable amount of fluorite. This mineral occurs both as dark, purple crystals embedded in the quartzite and as a mauve incrustation on joint-planes. The quartzite itself yielded only traces of P_2O_5.

The only other mineral noticed associated with the phosphate was calcite, which is occasionally seen lining cavities in the bed.

[1] Loc. cit., p. 183.

The above brief notes on the beds intimately associated with the phosphate, are sufficient to indicate the geologic association. A more detailed description of the Phosphoria formation is given below, in the description of the Sundance Canyon section.

NATURE OF THE PHOSPHATE.

The phosphate of the Banff area was found to be uniformly of the same general character at all the outcrops examined, though local degrees of weathering at different points sometimes produce slight variations in colour, hardness, and compactness.

The fresh, unweathered phosphate is black in colour, is extremely fine grained and compact, and possesses at first sight more the appearance of an igneous than a sedimentary rock.

A thin section of one of the purest samples of phosphate rock found (62·80 per cent $Ca_3(PO_4)_2$), showed numerous subangular quartz grains in a matrix of dark, amorphous phosphate. The dark colour of the latter would appear to be due to the presence of a bituminous substance.

The analysis of the above sample showed 24·82 per cent insoluble; thus, thin section and analysis combine to show that the chief impurity in the phosphate is silica, in the form of quartz grains. These quartz grains become locally quite abundant in the main bed, and we thus have a not infrequent transition of rather siliceous phosphate to what is, in effect, a phosphatic quartzite.

The specific gravity of the rock, as determined on one of the richest samples, is 3.

It is noteworthy that the oolitic structure, which is characteristic of certain of the Montana phosphates, is quite absent here.[1]

The rock is not noticeably heavier than the dark chert found some feet below the phosphate horizon, with which, indeed, it is often very liable to be confused, especially when the latter has become matt and earthy through weathering.

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[1] U. S. Geol. Surv., Bull. No. 530, 1913, p. 290.

The phosphate on breaking or pulverizing emits a certain characteristic odour, and this is sufficient to at once distinguish it from the earthy chert above alluded to. The odour is not strong[1] and does not persist for any length of time after the rock is broken; it may possibly be due to the bituminous matter mixed with the phosphate.

Fluorite is commonly present in the phosphate, both in the form of small crystal aggregates of a dark purple colour, and also as a mauve-coloured film on cracks in the rock.

The phosphate does not acquire, on weathering, the characteristic, bluish bloom that is so noticeable in the case of the oolitic Montana rock, and which is useful in tracing phosphate float in the latter region. On the contrary, the effect of weathering is, variously, to produce a somewhat rusty appearance or to deepen the black colour by rendering the rock slightly pulverulent on the surface. In one case, a slight efflorescence of a whitish colour was noticed on the face of the phosphate bed, and appeared to be due to the decomposition of pyrites in the phosphate.

The hardness of the fresh, unweathered rock is around 5, and the fracture is uneven, though sometimes inclined to subconchoidal. The latter fracture is due to the mode of occurrence of the phosphate in the bed. The phosphatic horizon is not by any means homogeneous; it is, rather, composed of an intimate association of phosphate and quartzite in varying proportions; the phosphate tending to form nodular or botryoidal masses in a quartzite matrix. This is not so evident in a fresh, unweathered section, nor where, as is sometimes the case, the phosphate is so largely in excess of the quartzite as to obscure the association. On exposure, however, the quartzite matrix seems to weather out more readily than the phosphate, leaving the latter standing out in nodular masses. These nodules commonly have a rough, pitted surface. They are not individuals, but appear to be botryoidal excrescences of a bedded deposit. (Fig. 1).

The quartzite matrix of the bed is phosphatic, and is of a pepper-grey to almost black colour, the colour deepening in

[1] Many of the beds of the Upper Banff Limestone are extremely fœtid, and such limestone, when dark in colour and fine grained, is liable to be mistaken for phosphate, especially in the case of float. In such case, the acid bottle is essential for determining the true nature of the material.

proportion to the amount of P_2O_5 present. This is evident from a number of qualitative tests made on such matrix material, the lighter coloured quartzite yielding only traces of a precipitate, while the grey and black rock were quite strongly phosphatic.

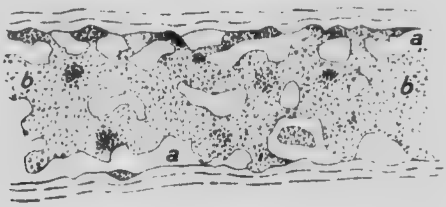


Fig. 1. Section of phosphate bed, showing nodular-massive occurence of the phosphate (*b*) in a matrix of phosphatic quartzite (*a*), Sundance Canyon.

That the proportion of phosphate to quartzite matrix is quite variable is evident from the analyses tabulated below, which are of samples taken from the entire bed-thickness at various points.

Analyses of representative samples of main phosphate bed from various outcrops in the Banff district.

Sample Number	Phosphoric acid P_2O_5	Equivalent to bone phosphate $Ca_3(PO_4)_2$	Lime CaO	Insoluble	Ferric oxide Fe_2O_3	Alumina Al_2O_3	Thickness of bed	Locality.
6	18·16	39·68	25·56	49·98	1·14	0·76	1 ft. 6 ins.	Sundance canyon.
14	20·68	45·19	31·58	39·02	0·71	0·46	0 " 11 "	" "
100	24·93	54·47	32·67	31·43	1·28	0·37	0 " 9 "	Mount Norquay.
102	8·39	18·33	15·20	66·34	1·28	0·36	2 " 0 "	" "
200	9·43	20·60	13·15	68·13	1·57	0·32	1 " 9 "	" "
300	27·38	59·83	36·72	26·58	1·00	0·53	0 " 11 "	Forty Mile creek
400	24·00	52·44	32·16	34·79	2·14	0·51	1 " 0 "	Bow river.
401	19·36	42·30	27·40	43·60	2·71	0·42	0 " 4 "	"
402A	27·63	60·37	36·18	29·75	1·57	0·43	1 " 0 "	"

These results indicate that, at a number of points, silica is certainly present in sufficient amount to constitute a very undesirable impurity.

The intimate association of the phosphate and quartzite would probably preclude any attempt to separate them by cobbing, should any exploitation of the deposits be attempted.

In the field, only a rough qualitative test for phosphoric acid was conducted on the various samples taken, all the analyses quoted in this report having been carried out by Mr. H. A. Leverin, of the Mines Branch.

The qualitative field test consisted in boiling one twentieth of a gramme of rock, rubbed to a fine powder in an agate mortar, with 5 cc. of dilute nitric acid. The solution was then filtered, and sufficient ammonia added to render it slightly alkaline. After adding a few drops of nitric acid, 20 cc. of ammonium molybdate solution were poured in. After standing for some hours, an approximate idea of the amount of phosphoric acid present was obtained by comparing the amount of precipitate with that obtained by similar methods from a series of phosphate rock samples of known composition and varying richness.

RESULTS OF THE EXAMINATION OF ROCKY MOUNTAIN QUARTZITE FOR PHOSPHATIC HORIZONS.

As noted above (p. 6), the Rocky Mountain Quartzite beds are found repeated in at least four northwest and southeast fault-belts in the Banff district. Each of these belts was examined for a phosphate horizon, the results of such examination being shown below under the headings of the respective belts.

I.

SAWBACK RANGE BELT.

As shown on the map, this belt is faulted just south of the Bow river, where its southeasterly extension is cut off. Northwest of this point the beds are well exposed on the southwest flank of the Sawback range, just north of the Banff-Castle road,

where they form the lower middle slope of the ridge. The lower slope is composed of talus, beneath which probably lie Permian shales, and the steep upper portion of the range is Upper Banff Limestone.

The first outcrop of the quartzite is met with at about 400 feet above the level of the Bow river, and the beds continue to 1,350 feet above river level, or for about 1,200 feet of slope. The dip is 55° S.W.

The series is very well exposed in the northwest wall of the canyon behind the game warden's house, and the beds also show up well along the flank of the mountain itself, west of the canyon; but the phosphate horizon is entirely absent in this belt at the point indicated.

The upper and outer Rocky Mountain Quartzite beds here consist of sandy-weathering and somewhat rusty quartzite, containing silicified corals. The black chert, which serves as a useful indicator of the phosphate bed at other points, and of which a considerable thickness is exposed in the fault strip immediately to the east, is not visible here, and is probably not represented.

The beds were examined for about a mile around the flank of the mountain, but no indication of phosphate was met with. It would appear that at least 150 feet of the upper Rocky Mountain Quartzite beds are either missing here or are concealed beneath talus. The Permo-Pennsylvanian contact is not exposed at any point along this slope.

The Rocky Mountain Quartzite consists here of alternating harder and softer, light coloured, calcareous quartzite beds; the softer layers having a tendency to weather out, leaving the harder beds as ledges with either flat terraces or depressions between them.

II.

SUNDANCE CANYON—MOUNT NORQUAY BELT.

A. Sundance Canyon.

The first discovery of phosphate in place was made in Sundance canyon.

Tilted beds of the Phosphoria formation, Sundance canyon. The top massive ledge is a harsh chert-quartzite, representing the uppermost section of the Rocky Mountain quartzite. Directly below it follow the phosphatic beds. The position of the main phosphate bed is indicated by the dotted line.

Outcrop of main phosphate bed (indicated by dotted line) in the northeast wall of Sundance canyon.

The upper beds of the Rocky Mountain Quartzite are particularly well exposed in the west wall of the canyon. The total length of the canyon proper is not more than 1,500 feet, and the difference in altitude of its bed from the upper or south end to the lower end is 250 feet. A small stream—Sundance creek—flows in the canyon and cascades down it in a series of small waterfalls. (See Plate I.)

About 350 feet up the creek from the southerly end of the canyon there is a small exposure of chert beds on the west side. This exposure consists of a small bluff, 150 feet long, and with a 35-foot face, which rises 50 feet back from the creek bank. The beds here exposed are solely the dark chert ledges below the phosphate horizon. Above the 35-foot fac this bluff is capped by a dirt slope, which conceals the upper, Phosphoria beds. Up stream, the valley widens out, and its lower slopes on both sides are formed of talus, there being no further exposure of the Rocky Mountain Quartzite for several miles. No attempt was made to pick up the beds at the southerly end of the valley.

The canyon proper exhibits a good section of the upper 100 feet of the Rocky Mountain Quartzite, and provides one of the best exposures of the phosphate horizon met with in the whole Banff area.

The section measured and sampled (see below) was about midway up the canyon, just above the second waterfall counting downwards, and in the west wall.

The total length of exposure of the phosphate bed in the west wall is 280 feet. Some 50 feet up stream from the measured section, the bed passes beneath talus on the slope of the hill above the canyon. Downwards, its exposure in the west wall is interrupted 60 feet above the mouth of the canyon by an abrupt turn in the course of the canyon, and the bed crosses to the east side, where it outcrops for 55 feet in the upper slope (Plate II). The bed then makes in under a 40-foot capping of talus on top of a small ridge, which forms the lower slope of the south side of the Bow River valley, and is first met with again across the valley, on the western flank of Mount Norquay (see map 387).

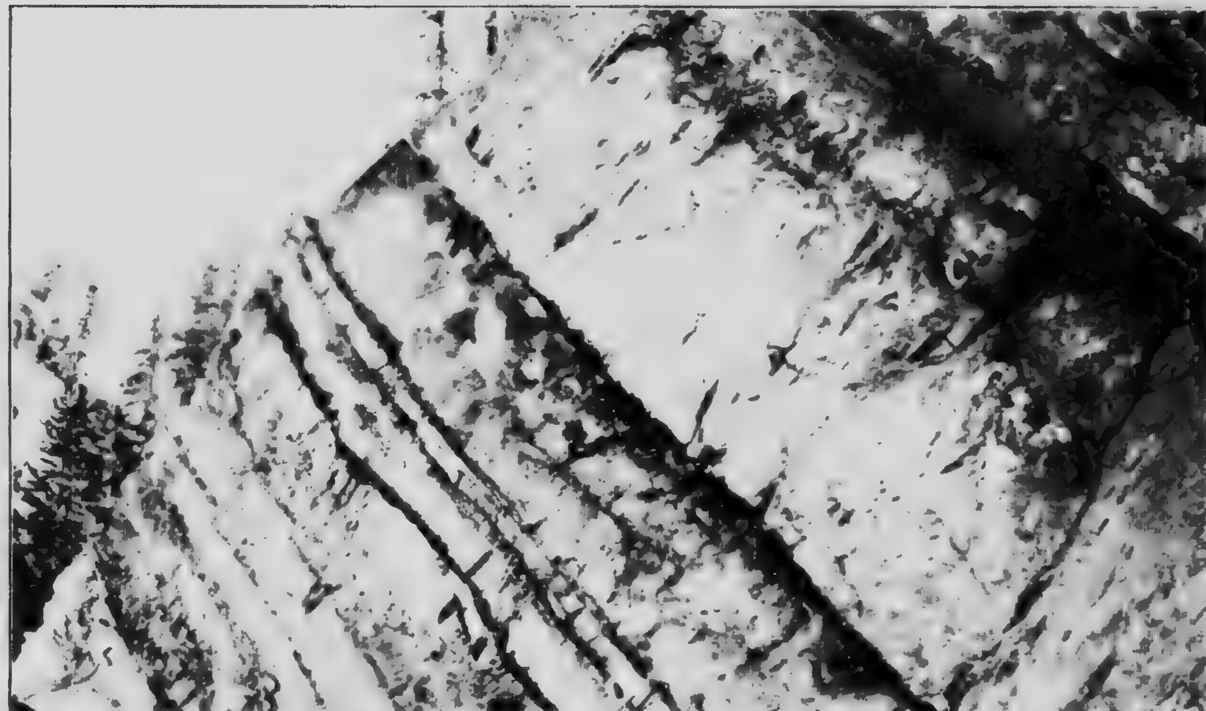
The phosphate bed proper, where exposed in a rock fa
has a pronounced tendency to weather out more readily than t
enclosing quartzite beds, and a depression is thus commor
formed in the face. The presence of such a depression m
prove of assistance in detecting the course of the bed acr
an inaccessible cliff, though it is not an infallible indicator, t
thinner quartzite ledges, also, sometimes displaying a simil
tendency to weather out.

Section of Phosphoria beds, Upper Rocky Mountai Quartzite, as exposed in Sundance Canyon.

Bed.	Thickness.		Character.	Phosphoric acid content.
	Ft.	*ins.*	Permo-Pennsylvanian Contact (?)	*Per cent.*
1	20	0	Harsh, grey chert-quartzite..........	....
2	0	8	Dark, cherty quartzite..............	0·61
3	0	1	Rusty, earthy parting..............	0·35
4	0	6	Dark grey quartzite..............	0·33
5	0	11	Thin layers of alternating dark quartzite and shale..............	0·26
6	3	6	Grey quartzite, with a 2-in. band of phosphate 6 ins. from top. The latter yielded	26·97
7	0	1	Rusty, earthy parting..............	24·38
8	1	6	Main phosphate bed. Grey quartzite matrix with nodular-massive black phosphate..............	18·16
9	0	1	Grey, earthy parting..............	18·13
10	0	8	Light grey quartzite..............	....
11	0	1	Rusty shale..............	30·60
12	2	3	Grey quartzite..............	....
13	1	4	Slate-grey quartzite..............	0·57
14	14	0	Grey quartzite......	....
15	7	5	Dark-grey quartzite..............	....
16	0	9	Grey, sandy shale..............	0·51
17	60+		Black chert beds (base of Phosphoria series)..............	

The strike of the series is N.22°W. and the dip 57°S.W. The strike and dip of the Rocky Mountain Quartzite beds are approximately the same as above in all four fault-strips in the

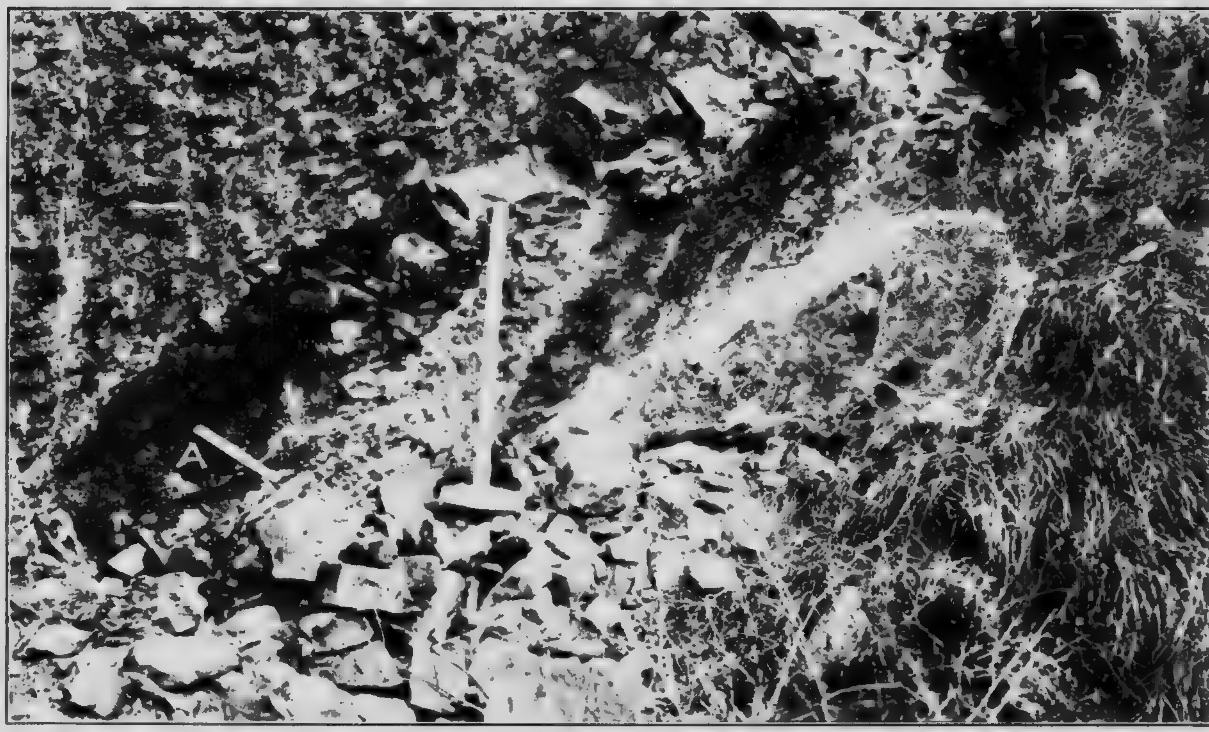
PLATE III.



Near view of main (18") phosphate bed (A) at measured section, Sundance canyon. Above this is a 3½-foot grey quartzite ledge (B) with a 2-inch phosphate band (C) near the top. The 1-inch, rusty shale seam (D) yielded the highest percentage of phosphoric acid (30·60) of any of the beds sampled.

Phosphoria beds at measured section, Sundance canyon. The main bed (A) lies some 6 feet below the chert-quartzite capping (B). Practically all the beds shown yielded some trace of phosphoric acid.

PLATE V.



Main phosphate bed (A) in southeast wall of Sundance canyon, some 50 feet north of the measured section. The bed here measures 11 inches. The characteristic, indented parting surface between the individual beds of the series is well shown.

Banff district; to the north, however, the beds appear to swing to a somewhat more northerly direction.

The prevailing colour of the phosphate bed on weathered surfaces is a sooty black, unless much silica is present, when it grades to a dirty grey. From the exposures examined, there would appear to be quite material local variations in composition and thickness. For instance, at the measured section the bed is greyish in colour, is 18 inches thick and appears to consist of a quartzite matrix with nodular phosphate through it and comprising some half of its mass. Twenty feet down the canyon, the bed thins to 11 inches (Plate V) and appears to consist mainly of phosphate with but little quartzite present. Across the Bow River valley, on the flank of Mount Norquay, the bed is 2 feet thick, and consists of a lower 12 inches of mixed massive phosphate and quartzite and an upper 12 inches of nodular-weathering phosphate with little silica.

The slate-grey quartzite bed immediately below the phosphate horizon contains considerable purple fluorite. This mineral has apparently been derived from the phosphate bed, and occurs in octahedra measuring up to ¼ inch across, embedded in the quartzite. The grey chert-quartzite at the top of the series also contains a little fluorite.

The top, massive chert-quartzite here is assumed to be the original upper portion of the Rocky Mountain Quartzite, upon which rested the Permian shales. The latter are not visible in place, however, the tilted chert-quartzite being quite bare at the lower [illegible] the canyon; while in a southerly direction it becomes c[illegible] by gradually thickening talus, which effectually concea[illegible] the rock formations. It seems probable, however, that little, if any, of the quartzite has been eroded and that the present surface is substantially the original one upon which the Permian shales were laid down.

The distance of the Sundance canyon phosphate outcrop from Banff is 3½ miles by road.

The thickness of the main phosphate bed where exposed in Sundance Canyon is from 11 to 18 inches.

The bed wa[illegible]npled at three points, as noted below, the samples being taken in the case of No. 6, by chipping pieces

from across the entire thickness, and in the other two instances by breaking out a piece of the bed.

Analyses of phosphate samples from Sundance Canyon.

	Sample No. 6.	Sample No. 6A.	Sample No. 14.
Weight of sample..	14·5 lbs.	14·5 lbs.	3 lbs
Thickness of bed..	18 ins.	7 ins.	11 ins.
Phosphoric acid..	18·16	28·74	20·68
Equivalent to bone phosphate..	39·68	63·58	45·19
Lime..	25·56	39·24	31·58
Insoluble..	49·98	24·82	39·02
Ferric oxide..	1·14	1·57	0·71
Alumina..	0·76	1·93	0·46

No. 6. Sample from main phosphate bed at measured section in southwest wall of canyon.
No. 6A. Lower 7 ins. of above bed, consisting chiefly of nodular phosphate.
No. 14. Sample from main phosphate bed in northeast wall of canyon.

B. Mount Norquay.

The northerly continuation of the Sundance Canyon Phosphoria beds is met with in several good exposures on the west flank of Mount Norquay.

The Rocky Mountain Quartzite here forms a steeply tilted cliff or wall above, and some 500 feet to the right of, the Mount Edith trail, which passes up the valley between Mount Edith and Mount Norquay. As at Sundance canyon, the softer Permian shales which originally rested against the quartzite have weathered down and are now concealed beneath a talus covering which occupies the valley between the two fault-strips.

The quartzite beds, which here have the same dip as in the Sundance canyon, *i.e.*, about 60° W., are well exposed (Plate VI) in a number of minor canyons or coulees which, on the southwest flank of the mountain have a southwest trend, cutting diagonally across the strata, which they tend to understope. On the west flank proper, however, the canyons cut through the quartzite more nearly normal to its strike. The narrowest

part of the coulees is at the mouth, or between the upper and outermost beds, and they gradually widen up the slope, so as to acquire more or less of a funnel shape as seen from above. These coulees are mostly occupied by rock-slides, the material of which is derived from the quartzite and from the limestone which forms the upper slope of Mount Norquay. They are nearly all short, being from 100 to 300 feet in length.

Outcrop 1.

The phosphate bed was first met in the third diagonal coulee from the road, on the southwest flank of the mountain. In the first two coulees, the horizon is concealed by talus from the upper quartzite beds, which has filled in the depression beneath the overhanging chert-quartzite ledges, and which probably covers the phosphate bed for a depth of 10-15 feet.

In this coulee the phosphate bed is 9 inches thick and consists of almost solid mineral. There is a 2-inch parting of nodular phosphate between the bed proper and the overlying chert-quartzite. Below the bed is a 15-inch ledge of light-coloured quartzite containing thin layers of phosphate in the lower 6 inches, but usually lean in its upper portion. The character of this bed, however, is not constant, and some feet farther up the coulee, phosphate appears to be present uniformly throughout the quartzite. Since the phosphate bed in the next coulee to the north is 2 feet thick, it is probable that this quartzite ledge should be reckoned to the phosphate horizon proper, and represents a lean and barren local phase of the same.

The phosphate in the upper 9-inch layer consists of large nodular masses in a matrix of dark grey quartzite. Fluorite appears to be almost entirely absent at this point, both in the phosphate itself and as bloom on joints in the underlying quartzite.

Outcrop 2.

In the fourth coulee from the road is presented one of the best sections of the upper Rocky Mountain Quartzite and Phosphoria beds to be met with in the Banff area. The mouth of this coulee opens 530 feet to the right of the trail and at a point

along the trail a little over ¾ mile from the Banff-Castle road.

The coulee is some 75 feet wide at its mouth or between the upper and outer quartzite beds. The Phosphoria series is exposed in both sides of the canyon, but as is the case in almost all the coulees on Mount Norquay, the north side offers the best section. The south side of the coulees is usually less steep than the north, and is commonly somewhat obscured by talus and growth.

The cliff on the north side offers a complete section of over 100 feet of the upper Rocky Mountain Quartzite beds. Below this, the continuation of the dark chert series is obscured by talus. The section presented is as under:

Section of Phosphoria beds, Upper Rocky Mountain Quartzite, as exposed on the west flank of Mount Norquay.

Bed.	Thickness.		Character.	Phosphoric acid content.
			Permo-Pennsylvanian Contact (?)	
	Ft.	*ins.*		*Per cent.*
1	86	0	Harsh, grey chert-quartzite	
2	0	9	Brown, earthy shale	....
3	4	0	Grey quartzite, with thin seams of nodular phosphate	0·64
4	2	0	Main phosphate bed. Black, nodular massive phosphate in a grey quartzite matrix	Not analysed.
5	22	0	Dark, cherty quartzite	8·39
6	6	0	Yellowish quartzite	
7	2+		Black chert beds (base of Phosphoria series)	

The phosphate bed possesses here the greatest thickness encountered in the whole Banff area and at the same time contains a larger proportion of silica. The Phosphoria series is shown in Plate VI. The 2-foot bed is divided into two separate portions, each 12 inches thick. The upper 12 inches consists of nodular-

PLATE VI.

Tilted phosphoria beds at measured section in coulee on west side of Mount Norquay. The main bed (A) possesses the greatest thickness (2 feet) observed in the area examined, but is low in phosphoric acid.

weathering phosphate, the surface being coated with a white, powdery efflorescence of sulphate of iron. The lower 12 inches is composed of a mixture of phosphate and yellowish-grey quartzite and is more massive in character.

All the phosphate weathers to a matt, sooty-black colour, and the upper bed, when broken up, readily yields a mass of round or ellipsoidal nodules averaging the size of an egg.

As shown above, the 2-foot phosphate horizon was sampled entire and showed a P_2O_5 content of only 8·39 per cent.

The strike of the beds here is N. 4° W.; the dip about 60° W. The beds thus have a rather more north and south trend than at Sundance canyon, distant 2½ miles across the Bow River valley, where the strike is N. 22° W.

The distance from Banff to the point where the Mount Edith trail meets the Banff-Castle road is about 4 miles, making the distance of the above described phosphate outcrop from Banff nearly 5 miles.

Outcrop 3.

In the fifth coulee from the road, the phosphate bed is exposed for a distance of 120 feet in the north side, the outcrop being nearly at the top of the slope. The thickness here is 21 inches, and an analysis of the rock gave 9·43 per cent. P_2O_5.

The next five coulees to the north disclose no exposures of the Phosphoria beds. The upper and outer chert-quartzite alone is visible here, the underlying series being concealed beneath talus.

Outcrop 4.

In the eleventh coulee, 40 feet of the phosphate bed are exposed in the north side. The thickness here is 21 inches, and the bed consists of large nodular masses of phosphate in a decomposed, quartzite matrix. No sample was taken here, the exposure resembling in every way that at outcrop 3.

Beyond the last outcrop, the shoulder of Mount Norquay flattens out to the northward and the quartzite is largely concealed beneath talus. This condition continues all the way to Forty-mile creek, where the still concealed beds pass over onto

the Vermilion range. No attempt was made to follow the phosphate horizon north of this point. It is probable, however, that the bed continues concealed for a considerable distance along the western flank of the above range, owing to the gently sloping nature of the lower slopes.

Analyses of phosphate samples from Mount Norquay.

	Sample No. 100.	Sample No. 102	Sample No. 200
Weight of sample	5 lbs	7·5 lbs.	8·5 lbs
Thickness of bed	9 ins	24 ins	21 ins
Phosphoric acid	24·93	8·39	9·43
Equivalent to bone phosphate	54·47	18·33	20·60
Lime	32·67	15·20	13·15
Insoluble	31·43	66·34	68·13
Ferric oxide	1·28	1·28	1·57
Alumina	0·37	0·36	0·32

No. 100. Sample from main phosphate bed in third coulee from road
No. 102. Sample from main bed in fourth coulee from road.
No. 200. Sample from main bed in fifth coulee from road.

III.

MOUNT RUNDLE—TUNNEL MOUNTAIN—CASCADE MOUNTAIN BELT.[1]

A. Mount Rundle.

No outcrops of the phosphate bed were found on Mount Rundle, but the horizon is probably concealed under talus along the lower western flank of the ridge. On the northwestern corner of the mountain, the Rocky Mountain Quartzite is met with at an altitude of only a few feet above the Spray river, but the Permo-Pennsylvanian contact is found at a steadily increasing height as one proceeds southward. At 5 miles from Banff, for

[1] Note: A slight alteration has been made on the accompanying map in the position of the geologic boundary between the Permian and Pennsylvanian, as indicated on Dr. Allan's map, in the Mt. Rundle—Stoney Squaw Mountain fault-block. This change was necessitated by the discovery of phosphate outcrops at points shown on Dr. Allan's map as occupied by Permian shales

Looking down on rock slide on west side of Mount Rundle towards the Spray river. Lower slope of Sulphur mountain in the background. The phosphate bed is not exposed; but its course probably lies in the neighbourhood of the dotted line, at an altitude of 600 feet above the river.

instance, in the side of the rock slide opposite the park engineer's temporary bridge, it is 600 feet above the river.

The lower slope of the western flank of Mount Rundle is covered consistently with a considerable depth of talus from the above mentioned bridge to the junction of the Spray and Bow rivers, and thus few rock outcrops are to be found except in the sides or beds of the occasional rock slides which have cut down through this talus and which extend usually from the Upper Banff Limestones above down to the Spray river.

In the slide immediately opposite the temporary bridge (Plate VII) and about 5 miles south of Banff, the Permian shales persist to 590 feet above the river. Above this, there is a talus interval for about 20 feet (altitude) and then the Rocky Mountain Quartzite appears. The upper beds, as here exposed, consist of sandy or shaly chert, and evidently belong below the phosphate horizon, which is probably to be found beneath the 20-foot talus strip. The rock slide material was examined for float phosphate, but none was found.

The same conditions as above were encountered in the slide some ½ mile farther north. Here, also, the Permo-Rocky Mountain Quartzite contact is not visible; but what are probably the beds immediately below the phosphate horizon are exposed in a small cliff on the north side of the slide, at an altitude of 615 feet above the river. The tendency of the phosphate to weather out more readily than the chert beds has probably resulted here in the removal by erosion of the phosphate and the overlying beds. The top bed here exposed is a 3½-foot grey quartzite ledge with a nodular parting 12 inches from the base. This parting is strongly phosphatic. Below lie dark chert and quartzite, which pass in under talus. The total section exposed here measures 12 feet.

B. Tunnel Mountain.

The Phosphoria beds are exposed for a length of 450 feet on the west side of Tunnel mountain. The phosphate horizon is terminated here in a southerly direction by a right-angled turn of the Bow river, which here takes on a northeasterly direc-

tion and has cut a channel almost normal to the strike of the strata. North of this point, the contact of the Permian shales with the Rocky Mountain Quartzite approximately parallels the course of the Bow river for some quarter of a mile, the actual contact being either at the base of the steep cliff of chert-quartzite which here forms the left bank of the river or a short distance out in the river bed. There was too much water to determine the actual line of contact, Still farther to the north, the river bank becomes lower and the quartzite is concealed under talus from the slope above.

Plate IX shows the steep wall of chert-quartzite forming the left bank of the river just above the point where it turns east.

At a point 450 feet up stream from the southernmost point of outcrop, the phosphate horizon passes into the river bed, owing to stream erosion of the uppermost quartzite.

At the most southerly outcrop, the phosphate bed is capped by 15 feet of chert-quartzite, and is about 12 inches thick. It appears, however, that the bed swells out into a sort of pocket here; and owing to stream-action having worn back the actual bed and the underlying dark chert for a distance of some 12 feet upstream, the bed itself could not be measured and the thickness had to be estimated. The thickness, however, is at least 12 inches, and the bed consists of more or less pure phosphate.

Below the phosphate is an 8-foot grey quartzite ledge containing considerable purple fluorite in its upper portions, and below this follow alternating dark chert and quartzite beds.

On the cliff above this point the bed shrinks to a 2-inch layer of nodular material, and from here, for a distance of 350 feet upstream, the horizon is represented by merely the thinnest phosphatic parting between the chert-quartzite and the underlying 8-foot grey quartzite ledge.

From here, however, the bed commences to thicken until at 380 feet up stream it measures 12 inches of nearly solid phosphate containing much purple fluorite. Between this point and where the bed passes into the river, 70 feet farther up stream, the thickness averages about 9 inches. The outcrop for this 70 feet is directly alongside the Tunnel Mountain lower road.

PLATE VIII.

Tilted Rocky Mountain quartzite beds at bend of Bow river below Spray falls, showing quartzite ledges standing out between softer calcareous or shaly beds. The Phosphoria series is shown by the line A, and the main phosphate bed by the dotted line.

PLATE IX.

View of Spray falls, Bow river. Permian shales form the right bank and occupy the greater part of the river bed. The left bank is formed of the top chert-quartzite of the Rocky Mountain quartzite. The main phosphate bed outcrops at A. The southwest flank of Stoney Squaw mountain is seen in the distance; the phosphate bed probably crosses this ridge in the neighbourhood of the dotted line, but is concealed beneath a heavy talus cover.

PLATE X.

Exposure of phosphoria beds at Spray falls, Bow river. The main phosphate bed occupies the position shown by the dotted line. The right bank of the river and the river bed itself are formed of Permian shales.

Some portions of the bed here exhibit a somewhat cavernous structure, calcite crystals and fossils being common in the cavities.

Samples of the phosphate bed taken along the above line of outcrops yielded the following:

Analyses of phosphate samples from Tunnel Mountain.

	Sample No. 400.	Sample No. 401.	Sample No. 402A.
Weight of sample	7·5 lbs.	7·5 lbs.	4·5 lbs.
Thickness of bed	12 ins.	4 ins.	12 ins.
Phosphoric acid	24·00	19·36	27·63
Equivalent to bone phosphate	52·44	42·30	60·37
Lime	32·16	27·40	36·18
Insoluble	34·79	43·60	29·75
Ferric oxide	2·14	2·71	1·57
Alumina	0·51	0·42	0·43

No. 400. Sample from main phosphate bed at bend of Bow river, opposite Banff Springs Hotel.
No. 401. Sample from main bed, 350 feet up stream from where No. 400 was taken. Bed contains fossils and calcite crystals.
No. 402A. Sample from main bed, 380 feet upstream from where No. 400 was taken.

C. Stoney Squaw Mountain.

The west flank of Stoney Squaw mountain was examined for outcrops of the phosphate bed, but without success.

The Rocky Mountain Quartzite forms the upper western slope of the mountain, and massive ledges of quartzite, separated by depressions occupying softer shaly horizons, project along the southwestern flank. These bea however, belong to a lower horizon than the phosphate, and the whole of the Phosphoria series, including the black chert beds, is concealed beneath talus. The actual course of the phosphate bed is probably not far to the

right of the Cascade Mountain trail, where it crosses the summit, between Mount Norquay and Stoney Squaw mountain.[1]

D. Cascade Mountain.

Only the extreme southwest flank of Cascade mountain was examined, there being a small exposure of the Rocky Mountain Quartzite here in a low cliff some 75 yards north of Forty-mile creek. These beds consist of somewhat sandy-weathering quartzite, and evidently belong below the phosphate horizon. Farther to the north along the western slope of the mountain, talus conceals the lower slopes and no outcrops of the phosphate are likely to be exposed, the course of the bed evidently lying along the eastern side of the valley between Cascade mountain and the Vermilion range.

Only one outcrop of the phosphate bed was found on Forty-mile creek, which runs between Cascade and Stoney Squaw mountains.

This outcrop is on the right or south bank of the creek, about 400 yards below the Cascade trail bridge. The total length of exposure here is only 3 feet, the phosphate bed occupying a crevice beneath a small mass of dark chert directly on the creek-bank. (See Plate XI).

The bed is 11 inches thick, and consists, where exposed, of solid phosphate throughout. An analysis of a sample taken here yielded 27·38 per cent P_2O_5, equivalent to 59·83 per cent tricalcic phosphate. This is the second highest percentage of phosphoric acid yielded by samples of the main phosphate bed in the Banff district.

The strike of the bed is N.28°W. and the dip 60°S.W. Directly above (south of) this outcrop, the ground rises towards the northwest flank of Stoney Squaw mountain, and all

[1] Note: It was on Stoney Squaw mountain that Adams and Dick found phosphate in place. The material consisted of very small pieces of phosphate in a quartzite ledge near the contact of the Rocky Mountain Quartzite with the Upper Banff Limestone and thus many feet below the main phosphate horizon. From field indications, the author is inclined to regard this occurrence as probably of little importance, many of the quartzite and chert beds of the Rocky Mountain Quartzite series containing small pieces or nodular fragments of phosphate. In the lower beds of the Rocky Mountain Quartzite, however, such phosphatic rock was in no instance found to be present in sufficient amount to constitute a definite phosphatic horizon.

Outcrop of main phosphate bed (A) between quartzite ledges on right bank of Forty-mile creek.

rock is concealed beneath the talus-covered slope. It would appear probable that the block of float phosphate found by Adams and Dick in the bed of the creek, a few miles farther down, came originally from this point.

Analysis of phosphate sample from Forty-mile Creek.

	Sample No. 300.
Weight of sample	7 lbs.
Thickness of bed	11 ins.
Phosphoric acid	27·38
Equivalent to bone phosphate	59·83
Lime	36·72
Insoluble	26·58
Ferric oxide	1·00
Alumina	0·53

IV.

CARROT OR STONEY CREEK—DEVIL'S CANYON BELT.

A. Carrot or Stoney Creek.

The Rocky Mountain Quartzite belt in the most easterly fault-strip shown on the map passes along the lower western slope of the Fairholme range and Mounts Peechee and Inglismaldie and by the western end of Lake Minnewanka.

The series is well exposed along Carrot or Stoney creek, which empties into the Bow river at a point about 9 miles by road southeast of Banff. The quartzite beds are best seen on the left or south side of the creek and are first met in a small ridge about a mile up the creek from where it crosses the road. There is a good trail up the creek.

The Permian shales are well exposed in several small knolls on the north side of the creek. Their actual contact with the quartzite, however, is obscured by drift.

The upper portion of the quartzite series, including the Phosphoria beds, appears to be entirely absent in this belt.

That is, the beds have not been eroded off, nor are they concealed beneath talus, they appear, on the contrary to either be quite unrepresented or to have been faulted off. This feature is presented alike at this point, in the canyon or coulee behind Anthracite and at Lake Minnewanka. It is, perhaps, best of all shown at the latter place (see below).

The uppermost beds of the quartzite exposed on Carrot creek consist of ledges of white quartzite, separated by thin layers of somewhat sandy shales, the whole evidently belonging to a horizon below the Phosphoria beds. No trace was found either of the dark chert or of the brown cherty shales which succeed the [illegible] Tunnel mountain fault-strip to the west. The quite considerable thickness of the quartzite is missing here. The apparent unconformity is, perhaps, to be attributed to over-riding of the quartzite by the Permian shales, the shales thus appearing to be in conformable contact with lower beds of the underlying formation; or it may be due to the downthrow of a narrow and hitherto unnoticed fault-strip which includes a portion of the shales and of the quartzite.

A short distance up stream from the last and lowest quartzite exposure, the creek has cut its way through a considerable thickness of Upper Banff Limestone, forming a high and narrow canyon some 30 feet in width and with perpendicular walls 75 to 100 feet high. The length of this canyon is not more than 100 feet.

Practically the same geologic conditions as described above are presented in the coulee extending down the slope of Mount Inglismaldie behind Anthracite, some 5 miles to the northwest.

B. Devil's Canyon.

A total thickness of about 500 feet of Rocky Mountain Quartzite is exceptionally well exposed in Devil's canyon, which forms the outlet of Lake Minnewanka. This canyon, the lake end of which is shown in Plate XII, has an average width of some 40 feet, is 500 feet long and 30 feet high. For its entire length it is in Rocky Mountain Quartzite beds. The lake edge, where is built the dam shown in Plate XII, appears to follow the

PLATE XII.

North end of Devil's canyon, showing dam at outlet, Lake Minnewanka. The beds shown are probably near the base of the Rocky Mountain quartzite, and the canyon, for the whole of its length (500 feet), is in this series. The course of the canyon is practically normal to the dip of the strata. The contact of Permian shales with the quartzite lies at the extreme end of the canyon, no trace of the Phosphoria formation was found in this fault strip.

approximate contact between the quartzite and the Upper Banff Limestone; that is, the beds at the dam probably represent the base of the quartzite.

At the lower end of the canyon, whose course is normal throughout to the strike of the strata, the ground falls away to the level of the Cascade river, and at the base of the tilted cliff is exposed the Permo-Pennsylvanian contact, dark shales lying against a white quartzite ledge. This contact, as in the case of the two above described localities on this belt, is apparently unconformable. There is no trace of the Phosphoria or dark chert beds here, and it is evident that several hundred feet of the quartzite beds are missing, the unconformity being due either, as suggested above, to over-riding by the shales or to down-faulting.

The dip of the quartzite beds is around 40° W. and their strike N.15°W. The series consists for its entire thickness of alternating dark grey and light coloured quartzite ledges, sometimes separated by thin, sandy-shaly partings. The two uppermost and outer ledges consist respectively of a 3½-foot white quartzite bed, followed by 13 feet of grey, somewhat sandy quartzite.

The same beds are exposed, also, in a parallel but shallower canyon, a few hundred yards to the southeast.

This belt was not examined north of Devil's canyon.

ECONOMIC IMPORTANCE OF THE DEPOSITS.

The above-described phosphate deposits can scarcely be regarded as of particular economic importance, since, as shown above, there is only one phosphate horizon of any consequence. This bed possesses an average thickness of about 12 inches, contains an average (as shown by nine analyses of material from the different outcrops) of 43·7 per cent tricalcic phosphate and 43·3 per cent of insoluble matter, chiefly silica in the form of quartz grains. Thus, in addition to having a low phosphoric acid content, the phosphate is most undesirable raw material for the manufacture of acid phosphate by the sulphuric acid process (the present commercial method), on account of the large

amount of inert silica that would unavoidably pass into the finished product. Assuming that the average silica content of the run-of-mine ore would be about 50 per cent, 100 tons of acid phosphate would contain about 25 tons of dead and worthless material in the form of quartz.

Even by cobbing out the more impure (siliceous) portions of the bed, the picked rock could probably hardly be brought to run much over 50 per cent $Ca_3(PO_4)_2$.

The dip of the phosphate bed is quite steep (about 55°). Thus, exploitation of the deposits would necessitate underground working and the removal of about three tons of dead rock to secure one ton of rather low grade phosphate.

On the other hand, in the event of an attempt to exploit the deposits, there are at least two localities in the Banff district where phosphate outcrops are situated favourably for working. Of these, the nearest to Banff is that at Sundance canyon, distant about 4 miles from Banff station. A good road runs to within a couple of hundred yards of this outcrop. The Mount Norquay outcrops (situated on the same bed as mentioned above and about 3 miles farther to the north across the Bow River valley) lie ¾ of a mile off the main road from Banff to Castle and 4 miles from Banff station, though the railroad itself runs within about a mile of the most southerly exposure. To exploit the bed at this point, it would be necessary to build a mine road of ¾ of a mile to the main highway; as the terrain to be traversed is easy, and a bridle trail already exists for practically the entire distance, this should not prove a difficult or expensive undertaking. The putting in of a railroad siding, also, would reduce the road-haul from 4 miles to hardly more than 1 mile.

As to the actual tonnage of phosphate rock available, the extent of the author's field work hardly permits of an estimate. Since there appears to have been but little important transverse movement or dislocation in the main fault-blocks, in the Banff region at least, there is no reason to consider that the course of the phosphate bed in the two centre fault-strips has been interrupted here to any extent by lateral faulting; it appears not unreasonable, therefore, to assume that the bed persists uninterruptedly for a considerable distance to the north and south of

Banff, concealed beneath the drift that covers the valleys and western flanks of the mountains.

Provided that the above assumption holds good in the case of the Sundance canyon—Mount Norquay bed (and the field indications gave no evidence to the contrary) we have between these points a total length between extreme outcrops of about 3½ miles.

The average thickness of the bed may be taken as 1 foot and the dip as 55°.

Now, at a specific gravity of 3·0, a cubic foot of phosphate rock weighs 187·5 pounds. There are, therefore, 4,084 short tons to the acre for every foot thickness of a flat-lying bed or 2,613,760 tons to the square mile.

Assuming that mining is practicable to a depth of half a mile, we have in the above 3½ miles section alone, 1¾ square miles of phosphate bed represented, or 4,574,080 short tons of phosphate rock. Owing to the nature of the terrain, however, and the fact that the Bow River valley, with a width of about a mile, crosses the bed midway between the located outcrops (see map), mining would probably be practicable only in the vicinity of these outcrops.

In the case of the Sundance canyon outcrops, a total length of bed of at least a quarter mile may be taken as minable. This, with a depth limit of half a mile, would give ⅛ of a square mile of bed available, or 326,726 short tons of phosphate rock. About twice the above length of outcrop may be taken for the Mount Norquay exposure giving 653,452 short tons of phosphate, or a total of close on a million tons for the two outcrops offering probably the greatest possibilities for development in the immediate Banff area.

The Tunnel mountain—Stoney Squaw mountain bed passes directly under the town of Banff, but the nature of the outcrop at the former locality hardly indicates the same possibilities for this bed as for that described above, the phosphate horizon for the greater portion of its course being concealed beneath a heavy cover of drift.

More detailed geological work both to the north and south of Banff, with especial attention to the existence of possible

transverse or subsidiary faulting, is essential before even an approximate estimate of the available tonnage of phosphate rock in these beds can be made.

Allan's map[1] of the Banff district extends about 6 miles to the north and 4 miles to the south of the Bow river, thus showing about 10 miles of the Rocky Mountain Quartzite beds as exposed in each of the two centre fault-strips, or 20 miles in all. These beds are nowhere shown as affected by transverse and faulting, and it may be assumed, therefore, that the phosphate horizon extends uninterruptedly for the above distance at least. This, with an average bed-thickness of 1 foot, and a depth limit for working of half a mile, would give 10 square miles of bed, or 26,137,600 short tons of phosphate rock for the area covered by Allan's map.

In the chief features presented, these deposits resemble the Silurian phosphate beds of North Wales.[2]

These latter also dip at quite a steep angle; the phosphate is black in colour and consists of nodular masses in a matrix of dark clay-slate. A little pyrites is present. The thickness of the main bed ranges from 6 to 18 ins. and the average tricalcic phosphate content is 46 per cent. Here, also, silica forms quite a considerable impurity, though not to the same extent (28·75 per cent). In contradistinction to the Alberta phosphate, the Welsh deposits are associated with limestones.

The Welsh phosphate was extracted by underground workings, but exploitation of the deposits ceased a number of years ago.

SUMMARY.

There are in the Banff district four parallel, approximately north and south fault-strips, in each of which is represented a certain thickness of Rocky Mountain Quartzite, the uppermost member of the Upper Carboniferous or Pennsylvanian formation.

[1] Guide Book No. 8, Part II, p. 188, Int. Geol. Congress, 1913.

[2] See Davies, "The Phosphorite Deposits of North Wales," Quart. Journ. Geol. Soc., Vol. 31, 1875, p. 357; also Geol. Mag., Vol. IV, 1867, p. 257, and Vol. II, 1875, p. 183.

Only in the two middle belts was the presence of a definite phosphate horizon established; in the western and eastern belts a considerable thickness of the upper quartzite beds (containing the Phosphoria or phosphate-bearing formation) is absent, having been either eroded, overridden or down-faulted.

The phosphate horizon occurs in the upper 50-60 feet of the Rocky Mountain Quartzite, and is overlain by massive, grey, harsh chert-quartzite. Below it follow beds of whitish or grey quartzite, often separated by thin, brown shaly partings, and these quartzites are underlain by black, dense chert. Many of the quartzites and shaly partings are phosphatic, but the only phosphatic horizon of any possible consequence is the main phosphate bed. The average thickness of this bed may be taken as 12 inches.

The phosphate is black in colour, and is very dense and compact. It is fine-grained and quite hard. Dark, purple fluorite is almost always present in some amount. The material of the bed consists variously of more or less pure, massive phosphate or of nodular masses of phosphate in a dark-grey quartzite matrix. The proportion of phosphate to silica in the latter case is distinctly variable at different localities.

The average dip of the phosphate bed and the enclosing quartzite series is 55° W.

The highest phosphoric acid content obtained from samples taken across the entire bed was 27·63 per cent, equivalent to 60·37 per cent bone phosphate.

The average of nine analyses of samples taken at four widely-separated points and in two adjacent fault-strips showed 20·0 per cent. P_2O_5 or 43·7 per cent $Ca_3(PO_4)_2$.

The highest content of ferric oxide was 2·71 per cent and the average 1·50 per cent, while the average iron and alumina combined amounted to 1·95 per cent. The iron and alumina content is thus well below the maximum of 3 per cent required by superphosphate manufacturers.

There are at least two outcrops of the phosphate bed that are conveniently situated as regards accessibility and transportation facilities, the one being about 4 miles from Banff station and the other hardly more than a mile from the railroad.

While unsuited to the manufacture of superphosphate by the sulphuric acid method, owing to the low content of tricalcic phosphate (average of nine analyses from various outcrops, 43·7 per cent[1]) and to the large amount of silica present (average of nine analyses, 43·3 per cent), the Alberta rock would possibly prove suitable for treatment by one of the thermic processes that have lately been proposed to supplant the sulphuric acid method.

Several of these processes are specially designed to employ low grade phosphate rock as raw material, the particular rock in view being impure, calcareous or clayey phosphates high in iron and alumina. None of the proposed methods, however, have as yet been proved commercial successes. With the advent of a commercial, thermic process, the natural gas resources of Alberta may perhaps prove an important factor in the possibility of utilizing this low grade Alberta phosphate.

For purposes of comparison, it may be stated that the most northerly Montana phosphate so far reported on by officers of the United Stated Geological Survey (that of the Elliston district, near Helena,) contains an average of 65 per cent tricalcic phosphate, the bed ranging in thickness from 3 to 5 feet. These deposits are situated from 2 to 7 miles from the Northern Pacific railway, and are regarded as readily capable of development.

The distance in a direct line from the Elliston outcrops to those of the Banff district is approximately 350 miles, and to the International boundary 190 miles. Assuming, as seems probable, that the Banff bed is a northerly extension of the Montana deposits, we have a belt of about 160 miles in Canada, along which phosphate outcrops may possibly be met with. The extension of the Phosphoria series to the north of Banff is not taken into account here.

In conclusion, while the thickness of the phosphate bed in the Banff area can hardly be regarded as sufficient to permit of profitable working of the deposit, yet the demonstrated existence of a definite phosphate horizon at a point thus far north of the Montana deposits, and conjecturally representing a northerly

[1] The better grades of rock employed for this purpose run 80 per cent and over $Ca_3(PO_4)_2$, the residue consisting mainly of calcareous material.

extension of these latter, is valuable as indicating the possibility of thicker and richer beds existing farther to the south in Alberta and nearer to the International boundary.

REGULATIONS GOVERNING QUARRYING OPERATIONS WITHIN DOMINION PARKS.

The leasing and administration of lands containing limestone, slate, marble, etc., and comprised within Forest Reserves and Parks, are governed by an Order-in-Council, P.C. No. 2140, dated 17th of September, 1915. By an additional Order-in-Council, P.C. No. 2293, dated 30th of September, 1915, the regulations contained in the above are extended to apply also to lands containing phosphate; and it is further provided that, pending the decision of the Parks Commission as to the advisability of drafting further regulations to apply to phosphate lands, no quarrying leases for phosphate shall be granted within the confines of the Dominion Parks.

The regulations contained in the above Order-in-Council, P.C. No. 2140, are as follows:—

1. No lease for quarrying purposes shall be granted for any area within a Dominion Park until the application has received the written approval of the Commissioner of Dominion Parks, or other official appointed by him, and unless he, or other official appointed by him, is satisfied that the granting of such lease will not mar the beauty of the Park or unduly interfere with the purposes for which it was established.

2. The area leased for quarrying purposes hereinafter referred to as the leasehold, shall include only such surface rights as shall be specified in writing by the Superintendent of the Park concerned, hereinafter called the Superintendent, as being required for active quarrying operations and any surface rights over any portion of a leasehold which are not thus specified may be disposed of by the Minister of the Interior, hereinafter called the Minister, for any purposes which, in the interests of such park, may be considered advisable.

3. The Minister may at any time resume possession of any portion or portions of the leasehold should he deem it necessary or advisable in connexion with the establishment and use of railway, transmission, telephone or telegraph lines, reservoirs, water power sites or any other works of a public or semi-public character, and an abatement will be made in the yearly rent at the rate of one dollar ($1.00) for every acre possession of which shall have been so resumed and the lessee shall have no claim for damages in any way resulting from such resumption.

4. No operations shall be commenced or proceeded with on any quarrying claim within any park until the Superintendent has been first advised in writing by the lessee, and until the Superintendent or other officer of the D partment of the Interior acting in the capacity of such Superintendent shall have given his written approval to the lessee of the work to be carried on.

5. The said lands shall be used for the purposes of the said quarrying operations and for no other purposes except with the consent of the Minister.

6. All earth, stone, refuse or other objectionable material which may accumulate through the operations of the quarry shall be disposed of by the lessee in a manner satisfactory to the Superintendent and in accordance with his instructions.

7. No nuisance or disorder shall be permitted on the leasehold and the land and works shall be kept in a clean and sanitary condition to the satisfaction of the Minister.

8. No rubbish or other objectionable material shall be removed from the leasehold and deposited in the park without written permission being first received from the Superintendent of such park.

9. It shall be lawful for the Minister or any person acting under his authority to enter upon the said leasehold and examine the condition thereof, at all reasonable times during the term of the lease.

10. Such royalty as may from time to time be fixed by the Governor-in-Council shall be paid by the lessee to the Minister or such officer as may be appointed to receive the same.

11. Any person or persons duly authorized by the Minister may quarry or carry away at any time from the leasehold, any stone or other material required for park purposes without compensation to the lessee, but in so doing no unnecessary interference shall be caused to the carrying on of the work of the lessee, and the lessee shall not be compelled to pay any royalty on such material so removed from the leasehold for park purposes.

12. The lessee shall not cut or interfere with any timber, trees or other vegetation on the said lands except to such an extent as in the judgment of the Superintendent is necessary to clear an area sufficient for the operation of the quarry and shall not impair the natural beauty of the park except to such an extent as in the judgment of the Superintendent is necessary for such quarrying operations.

13. The Superintendent may grant a permit to the lessee to clear off timber and other vegetation from an area sufficient for the operation of the quarry upon payment of timber dues as prescribed in the regulations for the Removal of Timber in Dominion Parks.

14. A proportionate share, as the Minister may decide, of the cost of fire and game protection in the vicinity of the leasehold shall be paid by the lessee.

15. The leasehold and the works and structures thereon, shall be maintained by the lessee in a manner satisfactory to the Superintendent of the park and if the quarrying operations terminate or cease through any cause

whatsoever at any time, the lessee, at the option of the Minister, shall remove or destroy without delay the buildings and other works placed by him on the leasehold, and shall deliver the leasehold to the possession of the Minister in an orderly and safe condition to the satisfaction of the Minister, and should the lessee fail to do this upon receipt of written instructions from the Minister, such refusal shall be accepted as a forfeiture of all rights or claims to the buildings or works and the same may be disposed of by the Minister in such a manner as he considers advisable and in the case of such disposal by the Minister the lessee shall have no right or claim for damages resulting therefrom.

16. The sites of all buildings, structures and shipping appurtenances to be erected on the said lands under this leasehold shall be subject to the approval of the Superintendent.

17. No building or buildings shall be erected on the leasehold without the Superintendent being first advised in writing, or before the Superintendent, or an officer of the Department appointed by him, shall have given his written approval to the lessee of the situation, style and design of the proposed building or buildings; and should the Minister at any subsequent time deem it wise or expedient for park interests that the said building or buildings be destroyed or removed to some other location or that the style or design of the building or buildings be changed, such destruction or removal or change shall be performed by and at the expense of the lessee, with all possible despatch.

18. Proper and sufficient provision, to the satisfaction of the Superintendent, for the protection of the public in connexion with blasting or other operations of a dangerous or offensive character, which may be necessary or desirable in connexion with the operations of the lessee, shall be made by the lessee, who shall be responsible for all claims or actions for damages to any person, persons or property, which may arise in any manner through his operations.

19. The lessee shall take such action at any time and in any manner as the Minister may direct or require to improve the conditions of the leasehold.

20. Such copies of the Park Regulations or general instructions regarding parks shall be posted and maintained by the lessee in a conspicuous position on the leasehold, as the Minister may direct from time to time.

21. The lessee shall comply with all the requirements of the Superintendent in respect to water supply, sewerage and sanitation and any other particular so as to protect public health and property.

22. The water in any lake, river, stream, or any body of water which may be on, or adjacent to, or flow through, or near any leasehold shall not be polluted or contaminated by the lessee or his employee.

23. The Minister may build any roads or trails through any leasehold, and all roads and trails which may cross any leasehold shall be kept open and in good repair by the lessee, and the public shall have free use of and access to all such roads and trails.

24. If any of the regulations are broken or violated by the lessee, the Minister may summarily cancel the lease or may stop all operations on the leasehold for such period or periods as he may direct, and the lessee shall have no claim for damages arising from any such cancellation of the lease or such suspension of operations.

25. Any lease made in pursuance of these regulations, and any renewal thereof, shall be subject to all regulations for the control and management of Dominion Parks now in force or which may hereafter be made from time to time by the Governor-in-Council.

CATALOGUE OF MINES BRANCH PUBLICATIONS

CANADA

DEPARTMENT OF MINES

HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS.

†1. Mining conditions in the Klondike, Yukon. Report on—by Eugene Haanel, Ph.D., 1902.

†2. Great landslide at Frank, Alta. Report on—by R. G. McConnell, B.A., and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

5. On the location and examination of magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones, and the lime industry of Manitoba. Preliminary report on—by J. W. Wells, M.A., 1905.

†8. Clays and shales of Manitoba: their industrial value. Preliminary report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic cements (raw materials) in Manitoba: manufacture and uses of. Preliminary report on—by J. W. Wells, M.A., 1905.

†10. Mica: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 118.)

†11. Asbestos: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

†12. Zinc resources of British Columbia and the conditions affecting their exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, M.E., 1905.

†16. *Experiments made at Sault Ste. Marie, under Government auspices in the smelting of Canadian iron ores by the electro-thermic process. Final report on—by Eugene Haanel, Ph.D., 1907.

†17. Mines of the silver-cobalt ores of the Cobalt district: their present and prospective output. Report on—by Eugene Haanel, Ph.D., 1907.

† Publications marked thus † are out of print.

†18. Graphite: its properties, occurrences, refining, and uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and lignite: their manufacture and uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron ore deposit of Nova Scotia. Report on (Part I)—by J. E. Woodman, D.Sc.

†21. Summary report of Mines Branch, 1907-8

†22. Iron ore deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron ore deposits along the Ottawa (Quebec side) and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General report on the mining and metallurgical industries of Canada, 1907-8.

†25. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D. (Out of print.)

26. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†27. The mineral production of Canada, 1907. Preliminary report on—by John McLeish, B.A.

†27a The mineral production of Canada, 1908. Preliminary report on—by John McLeish, B.A.

†28. Summary report of Mines Branch, 1908.

29. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel. (Supplemenatry section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

30. Investigation of the peat bogs and peat fuel industry of Canada, 1908. Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep, Peat Expert.

32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55 The bituminous, or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on)—by W. R. Ells, LL.D.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907-8.*

†31. Production of cement in Canada, 1908.

†42. Production of iron and steel in Canada during the calendar years 1907 and 1908.

43. Production of chromite in Canada during the calendar years 1907 and 1908.

44. Production of asbestos in Canada during the calendar years 1907 and 1908.

†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.

46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories at the Department of Mines, 1906-7-8. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analyses of oil-shales—by H. A Leverin, Ch.E.)

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

†71. Investigation of the peat bogs and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled 'A solution of the peat problem,' 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. Anrep. (Second edition, enlarged.)

82. Magnetic concentration experiments. Bulletin No 5—by Geo. C. Mackenzie, B.Sc.

Publications marked thus † are out of print

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
- Vol. I—Coal washing and cooking tests
- Vol. II—Boiler and gas producer tests.
- †Vol. III—(Out of print.)
  - Appendix I
    - Coal washing tests and diagrams.
- †Vol. IV—
  - Appendix II
    - Boiler tests and diagrams.
- †Vol. V—(Out of print.)
  - Appendix III
    - Producer tests and diagrams.
- †Vol. VI—
  - Appendix IV
    - Coking tests.
  - Appendix V
    - Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A.

> NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*
>
> †79. Production of iron and steel in Canada during the calendar year 1909.
>
> †80. Production of coal and coke in Canada during the calendar year 1909.
>
> 85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Proceedings of conference on explosives. (Fourth edition).

90. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Fourth edition.)

†93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

102. Mineral production of Canada, 1910. Preliminary report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

†103. Summary report of Mines Branch, 1910.

104. Catalogue of publications of Mines Branch, from 1902 to 1911, containing tables of contents and lists of maps, etc.

105. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

110. Western portion of Torbrook iron ore deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Frechette, M.Sc.

111. Diamond drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph.D., with introductory by A. W. G. Wilson, Ph.D.

118. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary report of Mines Branch, 1911.

143. The mineral production of Canada, 1910. Annual report on—by John McLeish, B.A.

Note.—*The following parts were separately printed and issued in advance of the Annual Report for 1910.*

†114. Production of cement, lime, clay products, stone, and other materials in Canada, 1910.
†115. Production of iron and steel in Canada during the calendar year 1910.
†116. Production of coal and coke in Canada during the calendar year 1910.
†117. General summary of the mineral production of Canada during the calendar year 1910.

145. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The mineral production of Canada, 1911. Preliminary report on—by John McLeish, B.A.

151. Investigation of the peat bogs and peat industry of Canada, 1910-11. Bulletin No. 8—by A. Anrep

154. The utilization of peat for fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

167. Pyrites in Canada: its occurrence, exploitation, dressing and uses. Report on—by A. W. G. Wilson, Ph.D.

170. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

201. The mineral production of Canada during the calendar year 1911. —Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.
†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.
183. General summary of the mineral production in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.
†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.
†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224.)

230. Economic minerals and mining industries of Canada.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E.

259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print

†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.

257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912 Report on—by John McLeish, B.A.

†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish. B.A.

285. Summary report of the Mines Branch, 1913.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—
Vol. I—Technology and Exploitation.
Vol. II—Occurrence of petroleum and natural gas in Canada.
Also separates of Vol. II, as follows:—
Part 1, Eastern Canada.
Part 2, Western Canada.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

309. The physical properties of cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

320. The mineral production of Canada during the calendar year 1913. Annual report on—by John McLeish, B.A.

Note.—*The following parts were separately printed and issued in advance of the Annual Report for 1913.*

315. The production of iron and steel during the calendar year 1913. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print.

316. The production of coal and coke during the calendar year 1913. Bulletin on—by John McLeish, B.A.

317. The production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year 1913. Bulletin on—by C. T. Cartwright, B.Sc.

318. The production of cement, lime, clay products, and other structural materials, during the calendar year 1913. Bulletin on—by John McLeish, B.A.

319. General summary of the mineral production of Canada during the calendar year 1913. Bulletin on—by John McLeish, B.A.

322 Economic minerals and mining industries of Canada. (Revised Edition).

323. The Products and by-products of coal. Report on—by Edgar Stansfield, M Sc., and F. E. Carter, B.Sc., Dr. Ing.

325. The salt industry of Canada. Report on—by L. H. Cole, B.Sc.

331. The investigation of six samples of Alberta lignites. Report on—by B. F. Haanel, B.Sc., and John Blizard, B.Sc.

333. The mineral production of Canada, 1914. Preliminary report on—by John McLeish, B.A.

334. Electro-plating with cobalt and its alloys. Report on—by H. T Kalmus, B.Sc., Ph.D.

336. Notes on clay deposits near McMurray, Alberta. Bulletin No. 1[illegible] by S. C. Ells, B.A., B.Sc.

344. Electrothermic smelting of iron ores in Sweden. Report on—by Alfred Stansfield, D.Sc., A.R.S.M., F.R.S.C.

346. Summary report of the Mines Branch for 1914.

348. Production of coal and coke in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

349. Production of iron and steel in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

350. Production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

383. The production of cement, lime, clay products, stone and other structural materials, during the calendar year 1914. Bulletin on—by John McLeish, B.A.

385. Investigation of a reported discovery of phosphate at Banff, Alberta. Bulletin No. 12—by H. S. de Schmid, M.E., 1915.

406. Description of the laboratories of the Mines Branch of the Department of Mines, 1916. Bulletin No. 13.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, Coal mines, Stone quarry operators, Manufacturers of clay products, and Manufacturers of lime. Copies of the lists may be obtained on application.

IN THE PRESS.

338. Coals of Canada: Vol. VII. Weathering of coal. Report on—by J. B. Porter, E.M., D.Sc., Ph.D.

351. Investigation of the peat bogs and the peat industry of Canada, 1913-1914. Bulletin No. 11—by A. Anrep.

384. The mineral production of Canada during the calendar year 1914. Annual Report on—by John McLeish, B.A.

FRENCH TRANSLATIONS.

†4. Rapport de la Commission nominée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

26a. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†28a. Summary report of Mines Branch, 1908.

56. Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

81. Chrysotile-asbestos, its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E.

100a. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

149. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

155. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

†156. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

169. Pyrites in Canada: its occurrences, exploitation, dressing, and uses. Report on—by A. W. G. Wilson, Ph.D.

179 The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

180. Investigation of the peat bogs, and peat industry of Canada, 1910-11. Bulletin No. 8—by A. Anrep.

195. Magnetite occurrences along the Central Ontario railway. Report on -by E. Lindeman, M.E.

† Publications marked thus † are out of print

†196. Investigation of the peat bogs and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second Edition, enlarged.)

197. Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D.

†198. Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

202. Graphite: its properties, occurrences, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

219. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

224a. Mines Branch Summary report for 1912.

†226. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

231. Economic minerals and mining industries of Canada.

233. Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

263. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

†264. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

286. Summary Report of Mines Branch, 1913.

287. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

289. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

290. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

† Publications marked thus † are out of print.

307. Catalogue of French publications of the Mines Branch and of the Geological Survey, up to July, 1914.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others—
   Vol. I—Coal washing and coking tests.
   Vol. II—Boiler and gas producer tests.
   Vol. III—
      Appendix I
         Coal washing tests and diagrams.

314. Iron ore deposits, Bristol mine, Pontiac county, Quebec, Report on—by E. Lindeman, M.E.

321. Annual mineral production of Canada, during the calendar year 1913. Report on—by J. McLeish, B.A.

IN THE PRESS.

204. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

223. Lode Mining in the Yukon: an investigation of quartz deposits in the Klondike division. Report on—by T. A. MacLean, B.Sc.

246. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

260. The preparation of Metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

2[illegible]0. The building and ornamental stones of Canada, Vol. III; Province of Quebec. Report on—by Professor W. A. Parks, Ph.D.

306. The non-metallic minerals nued in the Canadian manufacturing industries Report on—by Howells Fréchette, M.Sc.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others—
   Vol. IV—
      Appendix II
         Boiler tests and diagrams.

MAPS.

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906. (See Map No. 186.)

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12, concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred peat bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

†41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

*49 Magnetometric survey of Western Steel Iron claim, at Sechart, Vancouver island, B.C.—By E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

*53. Iron ore occurrences, Ottawa and Pontiac counties, Quebec, 1908—by J. White and Fritz Cirkel. (Accompanying report No. 23.)

*54. Iron ore occurrences, Argenteuil county, Quebec, 1908—by Fritz Cirkel. (Accompanying report No. 23.) (Out of print.)

†57. The productive chrome iron ore district of Quebec—by Fritz Cirkel. (Accompanying report No. 29.)

†60. Magnetometric survey of the Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†61. Topographical map of Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†64. Index map of Nova Scotia: Gypsum—by W. F. Jennison.

†65. Index map of New Brunswick: Gypsum—by W. F. Jennison.

†66. Map of Magdalen islands: Gypsum—by W. F. Jennison.

(Accompanying report No. 84.)

†70. Magnetometric survey of Northeast Arm iron range, Lake Timagami, Nipissing district, Ontario—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 63.)

†72 Brunner peat bog, Ontario—by A. Anrep.

†73. Komako peat bog, Ontario— " "

†74. Brockville peat bog, Ontario— " "

†75. Rondeau peat bog, Ontario— " "

†76. Alfred peat bog, Ontario— " "

†77 Alfred peat bog, Ontario main ditch profile—by A. Anrep.

(Accompanying report No. 71.)

(Out of print.)

†78. Map of asbestos region, Province of Quebec, 1910—by Fritz Cirkel. Scale 1 mile to 1 inch (Accompanying report No. 69.)

†94 Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts—by L. H. Cole. (Accompanying Summary report, 1910.)

†95. General map of Canada, showing coal fields. (Accompanying report No. 83—by Dr. J. B. Porter.)

†96. General map of coal fields of Nova Scotia and New Brunswick. (Accompanying report No. 83—by Dr. J. B. Porter.)

†97. General map showing coal fields in Alberta. Saskatchewan, and Manitoba. (Accompanying report No. 83—by Dr. J. B. Porter).

Note.—1. Maps marked thus * are to be found only in reports.
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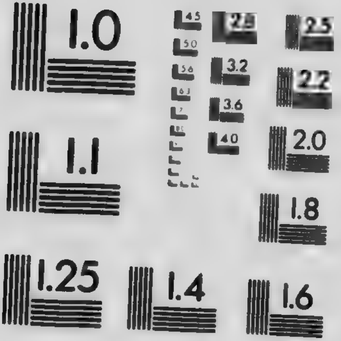
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†98. General map of coal fields in British Columbia. (Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General map of coal field in Yukon Territory. (Accompanying report No. 83—by Dr. J. B. Porter.)

†106. Geological map of Austin Book iron-bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†107. Magnetometric survey, vertical intensity: Austin Book iron-bearing district—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†108. Index map showing iron-bearing area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale 4,000 feet to 1 inch. (Accompanying report No. 111.)

†113. Holland peat bog Ontario—by A. Anrep. (Accompanying report No. 151.)

*119-137. Mica: township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: showing location of principal mines and occurrences in the Quebec mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†139. Mica: showing location of principal mines and occurrences in the Ontario mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†140. Mica: showing distribution of the principal mica occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†141. Torbrook iron-bearing district Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet to 1 inch. (Accompanying report No. 110.)

†146. Distribution of iron ore sands of the iron ore deposits on the north shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles to 1 inch. (Accompanying report No. 145.)

†147. Magnetic iron sand deposits in relation to Natashkwan harbour and Great Nataskwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains to 1 inch. (Accompanying report No. 145.)

†148. Natashkwan magnetic iron sand deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet to 1 inch. (Accompanying report No. 145.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†152. Map showing the location of peat bogs investigated in Ontario—by A. Anrep. (See Map No. 354.)

†153. Map showing the location of peat bog as investigated in Manitoba—by A. Anrep.

†157. Lac du Bonnet peat bog, Manitoba—by A. Anrep.

†158. Transmission peat bog, Manitoba— " "

†159. Corduroy peat bog, Manitoba — " "

†160. Boggy Creek peat bog, Manitoba— " "

†161. Rice Lake peat bog, Manitoba— " "

†162. Mud Lake peat bog, Manitoba— " "

†163. Litter peat bog, Manitoba— " "

†164. Julius peat litter bog, Manitoba— " "

†165. Fort Frances peat bog, Ontario— " "

(Accompanying report No. 151.)

*166. Magnetometric map of No. 3 mine, lot 7, concessions V. and VI, McKim township, Sudbury district, Ont.—by E. Lindeman (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mine to 1 inch. (Accompanying report No. 170.)

†172. Geological map of Victoria mine—by Prof. A. P. Coleman.

†173. " Crean Hill mine—by Prof. A. P. Coleman.

†174. " Creighton mine—by Prof. A. P. Coleman.

(Accompanying report No. 170.)

†175. " showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. " Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

Note.—1. Maps marked thus * are to be found only in reports.
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†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey, vertical intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits, Wollaston township, Hastings county Ontario—by E. Lindeman. 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191 Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

Note.—1. Maps marked thus * are to be found only in reports.
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192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey, vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a Geological map, Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway—by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario. Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet to 1 inch. (Accompanying report No. 303.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean (Accompanying report No. 222.)

†221. Dawson mining district, Yukon. Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

†239. Index map of Canada showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs in the Maritime provinces. Scale 100 miles to 1 inch. (Accompanying report No. 345.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles to 1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch (Accompanying report No. 254.)

Note.—1. Maps marked thus * are to be found only in reports.
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†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†261 Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom. 1903. Scale 200 feet to 1 inch.

†268. Map of peat bogs investigated in Quebec—by A. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec " "

†270. Small Tea Field peat bog, Quebec " "

†271. Lanoraie peat bog, Quebec " "

†272. St. Hyacinthe peat bog, Quebec " "

†273. Rivière du Loup peat bog " "

†274. Cacouna peat bog " "

†275. Le Parc peat bog, Quebec " "

†276. St. Denis peat bog, Quebec " "

†277. Rivière Ouelle peat bog, Quebec " "

†278. Moose Mountain peat bog, Quebec " "

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles to 1 inch. (Accompanying report No. 281.)

†293. ap of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspé oil Fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan, and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles to 1 inch (Accompanying report No. 291.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia—by E. Lindeman, 1913. Scale 200 feet to 1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†327. Map, showing location of Saline Springs and Salt Areas in the Dominion of Canada. (Accompanying Report No. 325).

†328. Map, showing location of Saline Springs in the Maritime Provinces. Scale 100 miles to 1 inch. (Accompanying Report No. 325).

†329. Map of Ontario-Michigan Salt Basin, showing probable limit of productive area. Scale 25 miles to 1 inch. (Accompanying Report No. 325).

†330. Map showing location of Saline Springs in Northern Manitoba. Scale 12½ miles to 1 inch. (Accompanying Report No. 325)

†340. Magnetometric Map of Atikokan Iron-Bearing district, Atikokan Mine and Vicinity. Claims Nos. 10E., 11E., 12E., 24E., 25E. and 26E., Rainy River district, Ontario. By A. H. A. Robinson, 1914. Scale 400 feet to 1 inch.

†340a. Geological map of Atikokan Iron-Bearing district, Atikokan mine and vicinity. Claims Nos. 10E, 11E, 12E, 24E, 25E and 26E Rainy River district, Ontario. By A. H. A. Robinson, 1914. Scale 400 feet to 1 inch.

†341. Magnetometric Map of Atikokan Iron-Bearing district, Sheet No. 1, Claims Nos. 400R., 401R., 402R., 112X. and 403R. Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†341a. Geological map of Atikokan Iron-Bearing district. Sheet No. 1. Claims Nos. 400R, 401R, 402R, 112X and 403R, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†342. Magnetometric Map of Atikokan Iron-Bearing district. Sheet No. 2. Claims Nos. 403R., 404R., 138X., 139X. and 140 X. Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†342a. Geological map of Atikokan Iron-Bearing district. Sheet No. 2. Claims Nos. 403R, 404R, 138X, 139X and 140X. Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

† Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†343. Magnetometric Map of Atikokan Iron-Bearing district. Mile Post No. 140, Canadian Northern railway, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†343a. Geological map, Atikokan Iron-Bearing district. Mile Post No. 140, Canadian Northern railway, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†354. Index Map, showing location of peat bogs investigated in Ontario— by A. Anrep, 1913-14

†355. Richmond peat bog, Carleton county, Ontario. " "

†356. Luther peat bog, Wellington and Dufferin counties, Ontario— " "

†357. Amaranth peat bog, Dufferin county, Ontario— " "

†358. Cargill peat bog, Bruce county, Ontario— " "

†359. Westover peat bog, Wentworth county, Ontario— " "

†360. Marsh Hill peat bog, Ontario county, Ontario— " "

†361. Sunderland peat bog, Ontario county, Ontario— " "

†362. Manilla peat bog, Victoria county, Ontario— " "

†363. Stoco peat bog, Hastings county, Ontario— " "

†364. Clareview peat bog, Lennox and Addington counties, Ontario— " "

†365. Index Map, showing location of peat bogs investigated in Quebec— " "

†366. L'Assomption peat bog, L'Assomption county, Quebec— " "

†367. St. Isidore peat bog, La Prairie county, Quebec— " "

†368. Holton peat bog, Chateauguay county, Quebec— " "

†369. Index Map, showing location of peat bogs investigated in Nova Scotia and Prince Edward Island— " "

†370. Black Marsh peat bog, Prince county, Prince Edward Island— " "

†371. Portage peat bog, Prince county, Prince Edward Island— " "

†372. Miscouche peat bog, Prince county, Prince Edward Island— " "

†373. Muddy Creek peat bog, Prince county, Prince Edward Island— " "

†374. The Black Banks peat bog, Prince county, Prince Edward Island— " "

† Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†375. Mermaid peat bog, Queens county, Prince Edward Island— by A. Anrep, 1913-14

†376. Caribou peat bog, Kings county, Prince Edward Island— " "

†377. Cherryfield Peat bog, Lunenburg County, Nova Scotia— " "

†378. Tusket peat bog Yarmouth county, Nova Scotia— " "

†379. Makoke peat bog, Yarmouth county, Nova Scotia— " "

†380. Heath peat bog, Yarmouth county, Nova Scotia— " "

†381. Port Clyde peat bog, Shelburne county, Nova Scotia— " "

†382. Latour peat bog, Shelburne county, Nova Scotia— " "

†383. Clyde peat bog, Shelburne county, Nova Scotia— " "

†387. Geological map Banff district, Alberta, showing location of phosphate beds. By Hugh S. deSchmid, 1915: accompanying report No. 385.

†390. Christina river map showing outcrops of bituminous sand along Christina valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to inch.

†391. Clearwater river map, showing outcrops of bituminous sand along Clearwater valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†392. Hangingstone-Horse rivers, showing outcrops of bituminous sand along Hangingstone and Horse River valleys: contour intervales of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†393. Steepbank river, showing outcrops of bituminous sand along Steepbank valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†394. McKay river, 3 sheets, showing outcrops of bituminous sand along McKay valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†395. Moose river, showing outcrops of bituminous sand along Moose valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

Address all communications to—

DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
SUSSEX STREET, OTTAWA.

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

CANADA

DEPARTMENT OF M

MINES BRANCH

HON. P. E. BLONDIN, MINISTER; R. G. McCONNE

EUGENE HAANEL, PH. D., DIREC

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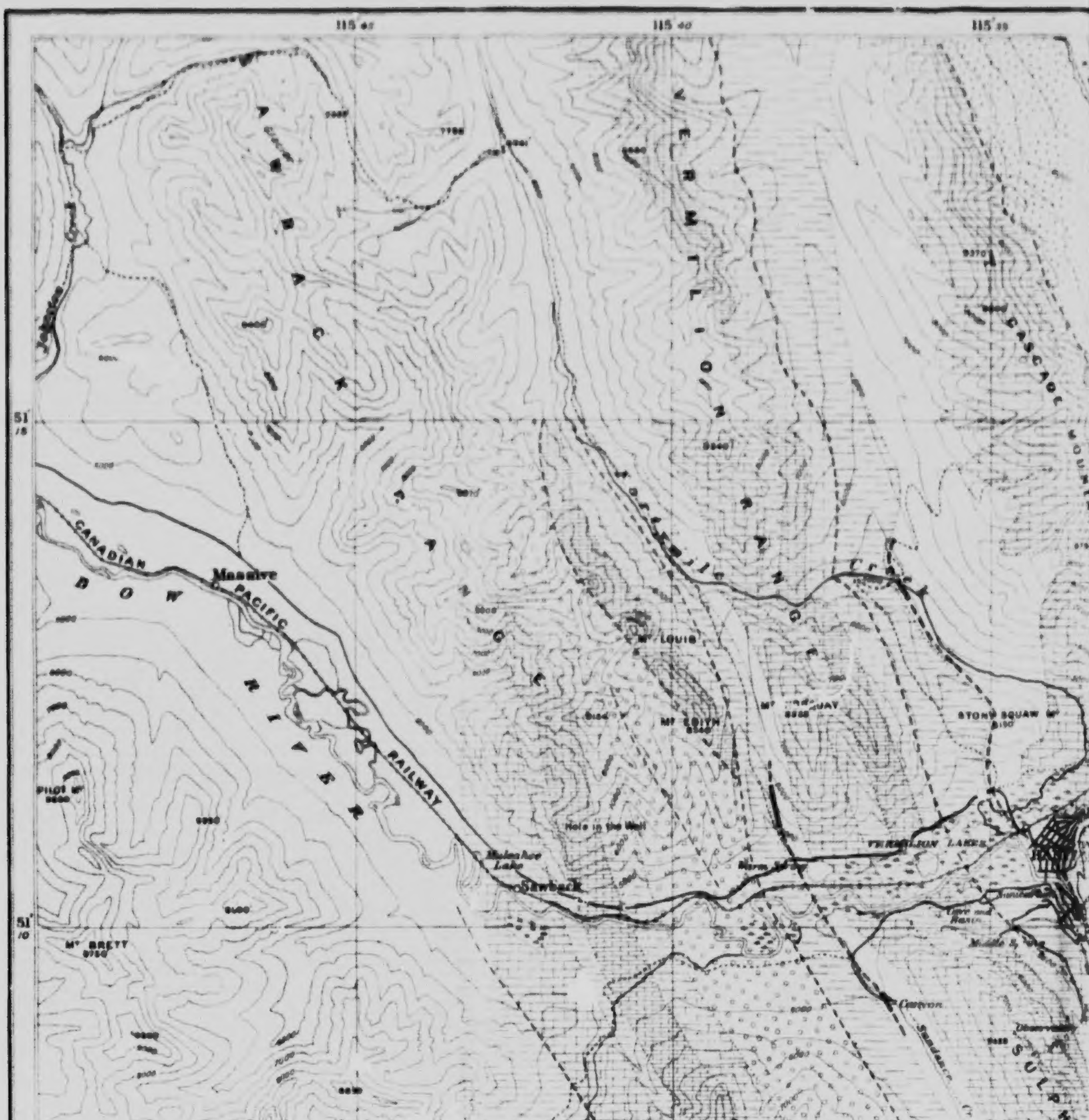

Base map, Department of the Interior.
Geology compiled from maps by J.A. Allan and D.B. Dowling,
Geological Survey of Canada.
Phosphate outcrops by Hugh S. de Schmid, 1915.

GEOLOGICAL MAP (

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SHOWING LOCATION OF PHOS

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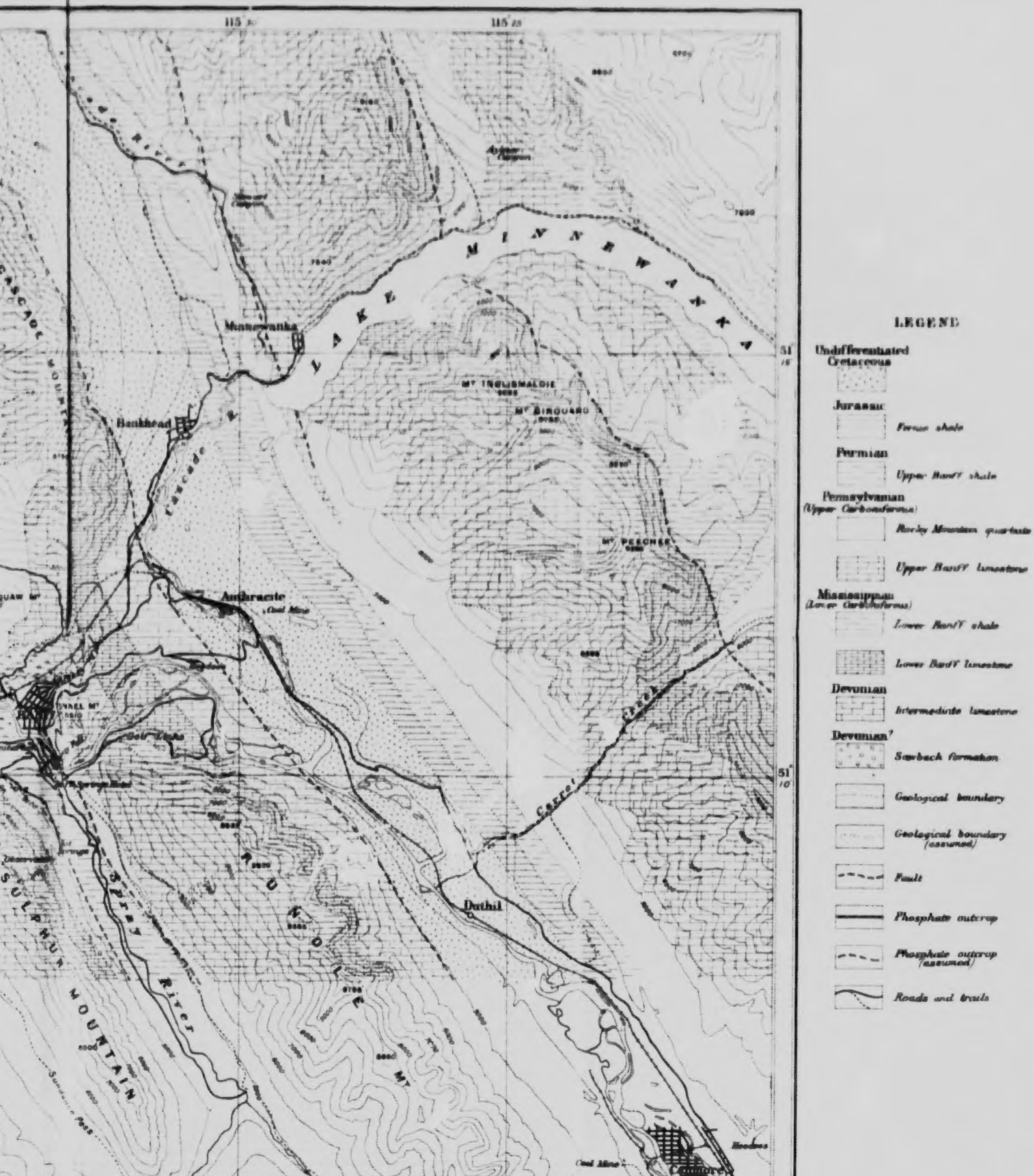

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MAP OF

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RTA

OF PHOSPHATE BEDS

2 3 4 Miles